



Report of the
Defense Science Board
Task Force on

Time Critical Conventional Strike from Strategic Standoff

March 2009

Office of the Under Secretary of Defense
for Acquisition, Technology, and Logistics
Washington, D.C. 20301-3140

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE MAR 2009		2. REPORT TYPE		3. DATES COVERED 00-00-2009 to 00-00-2009	
4. TITLE AND SUBTITLE Time Critical Conventional Strike from Strategic Standoff				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Office of the Under Secretary of Defense, For Acquisition, Technology, and Logistics, Washington, DC, 20301-3140				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 101	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

This report is a product of the Defense Science Board (DSB). The DSB is a Federal Advisory Committee established to provide independent advice to the Secretary of Defense. Statements, opinions, conclusions, and recommendations in this report do not necessarily represent the official position of the Department of Defense.

The DSB Task Force on Time Critical Strike from Strategic Standoff completed its information gathering in April 2007. This report is UNCLASSIFIED and releasable to the public.



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MEMORANDUM FOR UNDER SECRETARY OF DEFENSE FOR ACQUISITION,
TECHNOLOGY AND LOGISTICS

SUBJECT: Final Report of the Defense Science Board (DSB) Task Force on Time
Critical Conventional Strike from Strategic Standoff

I am pleased to forward the final report of the DSB Task Force on Time Critical Conventional Strike from Strategic Standoff, co-chaired by Dr. Ronald Kerber and Mr. Robert Stein.

As requested in the Terms of Reference (TOR) the Task Force was asked to evaluate a complete range of time-critical conventional strike options within several realistic scenarios. The Task Force tried to explore and illuminate various attributes associated with the different means of accomplishing a time-critical conventional strike from strategic standoff capability. The TOR pinpointed four parameters of interest to focus on: target set, accuracy, basing, and kill mechanism. In addition, the Task Force was asked to assess each alternative strike capability using four principal measures of effectiveness and issue specific recommendations for preferred approaches based on specific dominate requirements.

The final report addresses each tasking in the Terms of Reference and offers findings and recommendations derived from a scenario-based analysis. The findings and recommendations include both strike options as well as key enablers that must be effective if a time critical strike from strategic standoff is to be successful. Recommendations are provided in the areas of ISR; planning and exercising; munitions; hardened underground facility defeat; SOF; dynamic fire control; air-breathing delivery vehicles; integration and exercising of combined operations C3I. Due to the nature of the study, the findings and recommendations of the Task Force are presented in a full classified report and an unclassified Executive Summary.

I endorse the Task Force's findings and recommendations and encourage your review.

A handwritten signature in black ink, reading "William Schneider, Jr.", is positioned above the printed name.

Dr. William Schneider, Jr.
Chairman

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DEFENSE SCIENCE
BOARD

October 15, 2008

MEMORANDUM FOR THE CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Final Report of the Defense Science Board (DSB) Task Force on Time Critical Conventional Strike from Strategic Standoff

The Undersecretary of Defense for Acquisition, Technology and Logistics directed the Defense Science Board to form a Task Force on time-critical conventional strike from strategic standoff. The Terms of Reference (TOR) asked the Task Force to explore and identify the various attributes associated with the different means of accomplishing a prompt, conventional strike capability when no U.S. forces are in the region and to illuminate the tradeoffs associated with each alternative. In addition the TOR requested the Task Force to evaluate these alternatives within several realistic scenarios. The TOR included four parameters of interest: target set, accuracy, basing, and kill mechanism; and four principal measures of effectiveness from which to assess each alternative capability: time to strike, cost, development risk, and other (e.g. policy issues, current treaty prohibitions, special training requirements, etc.).

The Task Force hypothesized circumstances in which a standoff strike capability could be critical to defeating a threat to U.S. interests: countering terrorism, countering WMD, etc. While a weapon or weapon system may be a critical component for a military option, we found that certain key enablers must be effective if a time critical strike from standoff is to be successful. The key enablers include a robust ISR capability and integrated command, control, and communication (C3).

The Task Force formulated five representative scenarios that contained all the driving issues associated with the remote rapid strike problem, including those contained in the Department's planning scenarios. The five scenarios were expected to require a very rapid strike response to a developing situation and to provide a broad range of challenging issues. All potential current and future response capabilities that might satisfy mission objectives were examined under a range of CONOPS using all available options for hard kinetic strike, Special Operations, Information Operations, and other capabilities. The critical enabling functions of C3 and ISR were considered.

A number of findings resulted from the scenario-based analysis and evaluation.

- The solution to “time critical” is not necessarily weapon speed.
- None of the scenarios exposed a need for “one hour, global range delivery.” There appears to be nothing unique or compelling about one hour.
- Systems which attack overtly against fixed coordinates from extreme range do not provide a watershed capability nor are they usually mission-effective.
- Covert, loitering strike systems enabled by robust target ISR and tracking, C3 and fire control capabilities would revolutionize global strike for both the long war and for deterrence of rogue and near-peer nations.
- Special Operations Forces (SOF) are often preferred to kinetic strike because of their ability to render a target rather than destroying it and/or creating collateral damage.
- The most cost-effective enhancements to current capabilities appear to come from two new types of munitions and warheads; strike delivery platforms focused on non-stationary targets; enhancements to ISR capabilities; improvements to provide robust global communications, rapid adaptive command and control and mission pre-planning systems; and capabilities to rapidly deliver, support and extract SOFs from long distances.
- Because planning and decision time may swamp weapon delivery time, realistic exercise of the entire planning and decision making process, including involvement of the principals, is critical
- The current DoD focus on delivery platforms for time-critical strike needs to be balanced with a considerably increased focus on ISR, munitions, C3, SOF and exercises.

Based on its findings, the Task Force offers recommendations in the following areas: ISR; planning and exercising; munitions; hardened underground facility defeat; SOF; dynamic fire control; air-breathing delivery vehicles; integration and exercising of combined operations C3I.

The attached abridged report provides an Executive Summary which offers further detail on the Task Force’s findings and recommendations; a background section which discusses previous studies and current capabilities; a strike options tutorial and detailed scenario descriptions. The full report is classified and provides a more complete and detailed rationale for the Task Force recommendations. A copy of the full report may be obtained by contacting the DSB office.



Dr. Ronald Kerber
Co-Chairman



Mr. Robert Stein
Co-Chairman

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EXECUTIVE SUMMARY

This Executive Summary and the attached appendices provide an unclassified overview of the Task Force analysis, findings and recommendations. For a more detailed understanding of this material, we refer the reader to the classified version of the full report.¹

The U.S. strategic deterrence and strike environment has changed as our adversaries and their tactics have changed. Terrorists and rogue nations as well as future potential peers are well aware that asymmetric tactics are proving very effective against our forces. In the past, a weapon of mass destruction (WMD) was a weapon of last resort for virtually all of the Nation's primary adversaries – it now may be moving closer to the weapon of choice, at least for some. Terrorist leaders are more willing to take risks, tend to place much less value on the life of individuals, have much less to lose, and are somewhat protected by “statelessness.” Avowed tactics included massive targeting of innocents, martyrdom of “soldiers,” and operating within a civilian environment. Operational “fuzziness” makes Indications and Warnings (I&W) much more difficult and/or fleeting. WMD technology is broadly available, and the cost of entry is much lower than for traditional, indigenously developed, nuclear weapons. At the same time rogue nations are aggressively pursuing nuclear weapon capability. Deterrence has become more elusive in terms of identifying and locating adversaries, understanding adversary values, and understanding what of the adversaries the United States (U.S.) can hold at risk. Our future global strategic strike capability must recognize today's realities, be highly effective, quickly and easily usable, yet in many situations inflict minimal collateral damage while maintaining the threshold for nuclear weapons use at the high level we observe today. This all gives rise to the need for a prompt, conventional strike capability, deliverable to almost anyplace on the globe.

Time critical conventional strike from long standoff ranges into restricted or denied territory has been an operational, policy, and acquisition challenge for a long time, and this topic appeared in many studies and reports as a hard problem for which no satisfactory solution appeared to be readily available. In situations in which time is not a factor and/or in which sufficient U.S. forces are deployed nearby, the U.S. has demonstrated its ability to strike at identified threats effectively. However, in situations in which time is a factor and no nearby forces are present, if Courses of Action (COA) are requested, only two options are currently available; nuclear Intercontinental Ballistic Missile Systems (ICBMs)/Submarine/Sea-Launched Ballistic Missile (SLBMs) or no military action.

Many circumstances have been postulated in which a standoff strike capability could be critical to defeating a threat to U.S. interests; countering terrorism, countering WMD, countering proliferation, countering an emerging disruptive capability to name a few. While a weapon system or systems may be a critical component for a military option, there are also key enablers that must be effective if a time critical strike from standoff is to be successful. Foremost among the enablers is a robust Intelligence, Surveillance, Reconnaissance (ISR) capability that can provide warning, target identification and target location while functioning within the adversary's decision cycle to provide positive warning, localization and identification that meets the national decision maker's threshold to proceed with a strike. An integrated Command,

¹ For access to the full report contact the Defense Science Board office at 703-571-0081.

Control, and Communication (C3) is a second key enabler that is critical to effectively providing national leadership with a prompt global strike option.

Early in the study, the Task Force determined that a scenario-based analysis would be useful in identifying the critical issues and evaluating the options and possible Concepts of Operations (CONOPS) for time-critical conventional strike. The Task Force formulated five representative scenarios that contained all of the driving issues associated with the remote rapid strike problem, including those contained in the Department's Planning Scenarios. These issues included variations in adversary type, U.S. objectives, target type and mobility, time to strike, available preparation time, surety of target ID, collateral damage, battle damage assessment, possible adversary response and deniability and proportionality. The five scenarios are summarized below.

1. Near-Peer Competitor with an emerging counter-space capability has destroyed a U.S. Low Earth Orbit (LEO) satellite. The U.S. desires to prevent future damage to other satellites in the constellation, but with minimum potential for escalation of hostilities. Key scenario characteristics – easiest scenario, provides good baseline.
2. Terrorist organization ships a large package of special nuclear material (SNM) by rail to a transfer point in a neutral country, after which the SNM will be shipped to an unknown location. The U.S. desires to capture or destroy the material while its location is known. Key scenario characteristics – collateral damage, preparation time, tip-off, BDA.
3. Uncharacterized WMD in a small package is located and temporarily static in a rural area of a neutral country. The U.S. desires to capture or destroy the package while its general location is known. Key scenario characteristics – specific target location/ID, covertness of prep/attack, total destruction without local or area contamination, BDA.
4. Terrorist organization leadership is expected to gather in a public building in the capital city of a neutral country. The U.S. desires to kill or render all meeting participants. Key scenario characteristics – surety of meeting location and time, ID of assembled people, covertness of prep/attack, collateral damage, plausible deniability, rendering preferable to killing.
5. Rogue state holding coalition ally and U.S. hostage to nuclear blackmail. U.S. desires to totally deny capability to deliver any nuclear weapons with a high degree of certainty. Key scenario characteristics – hard/soft and fixed/mobile target set, difficulty of entry, surety/confirmation of destruction.

All five scenarios were expected to require a very rapid strike response to a developing situation. All potential current and future response capabilities that might satisfy mission objectives were examined using all available options for hard kinetic strike, Special Operations, Information Operations (IO), and other capabilities. The critical enabling functions of C3 and ISR were considered. The only significant “going in” assumption was the existence of actionable intelligence. The scenarios were purposefully constructed to provide a broad range of different challenging issues within the global strike arena, including the number and hardness or temporal

nature of the targets, the degree of time urgency and need to avoid any kind of tip-off, the target clutter background and ID issues, collateral damage restrictions, treaty implications and “fly over” restrictions, the required surety and confirmation of mission success and the permissiveness of the host nation security environment. All scenarios reflect major U.S. security interests and potential threats around the globe. The method with which the Task Force analyzed and evaluated each scenario is shown in Figure 1.

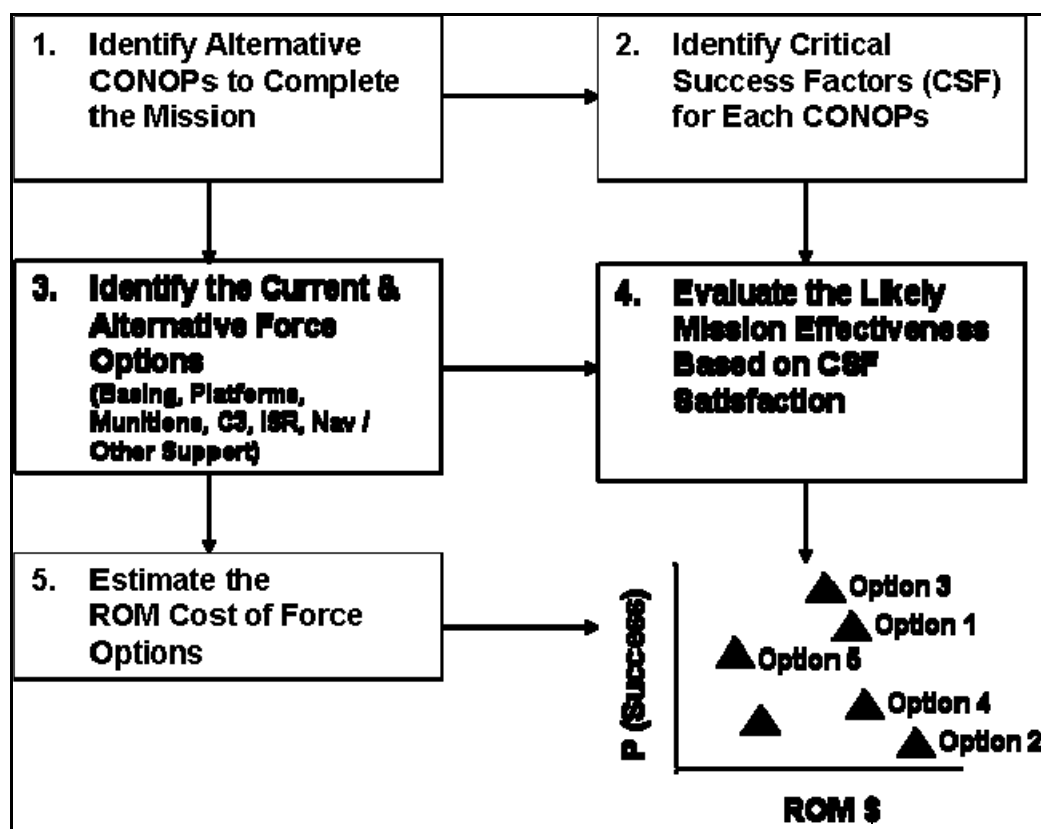


Figure 1: Evaluation Approach

Each scenario was characterized in terms of the United States’ mission objectives and pertinent operating conditions and constraints. Next, a set of alternative Concepts of Operations (CONOPs) for conduct of the mission were defined. These CONOPs considered not only the mission objectives and conditions and/or constraints, but the current capabilities and doctrine for existing global strike systems and alternative CONOPs which might be enabled by new capabilities.

The Task Force considered elements of the current force and a range of future alternatives derived from funded and unfunded programs, government and industry concepts, and internally-created options. The options best suited to each CONOP alternative were evaluated in detail against the mission needs, critical success factors (CSF) and their effectiveness for each scenario.

Although the Task Force did not perform detailed independent cost estimates on the alternatives, it made rough order of magnitude (ROM) estimates of the cost to develop and field the alternatives. Thus, for each scenario and each potential strike option, both effectiveness and cost

data were developed. These data were combined across the ranges of scenarios, overall cost-effectiveness was determined for each alternative and the underlying reasons why certain classes of alternatives turned out to be more cost-effective and useful in a broad range of applications were noted.

A number of principal findings resulted.

Perhaps the most significant finding is that the solution to “time critical” strike is not necessarily weapon speed. In fact, weapon fly out time is but one component of the entire response time to an event. The rest of the time cycle includes decision making, preparation, strike planning, moving resources into position, etc., and can often dwarf the impact of weapon delivery time. The Task Force believes that many of these more lengthy time components can be reduced through effective preplanning and exercising.

In spite of setting out to develop scenarios suitable for examining very rapid global strike needs and capabilities, none of the scenarios exposes a need for “one hour, global range delivery.” On close examination, there appears to be nothing unique or compelling about one hour. The operationally relevant meaning of “time urgent” is far more nuanced, and varies from minutes to many hours. The time available can almost always be increased by taking some action or actions other than immediate strike. It also appears that, in addition to increasing the time available to respond, such actions actually enhance the likely success of the mission as well as increase the options available to decision makers. Lastly, owing to the global basing of U.S. forces, intercontinental delivery is usually unnecessary.

High value adversary capabilities are almost always mobile and have the ability to react rapidly to any sign of U.S. attack. This implies a need for strike capabilities which attack with surprise and can adapt en-route to changes in target location and status. Systems which attack overtly against fixed coordinates from extreme range are usually not mission-effective. Successful CONOPs generally involve loitering in a region, surveilling and tracking targets, and striking from moderate ranges, all done covertly to achieve surprise. While not currently programmed by DoD and the Intelligence Community (IC), a transition to covert, loitering strike systems enabled by robust target ISR, ID and tracking, C3 and fire control capabilities would revolutionize Global Strike for both the Long War and for deterrence of rogue and near-peer nations.

Special Operations Forces (SOF) are often preferred to strike because of their ability to render a target rather than destroying it and/or creating collateral damage.

The most cost-effective enhancements to current capabilities appear to come from (1) a few new types of munitions and warheads, (2) strike enhancements focused on non-stationary targets, (3) enhancements to ISR capabilities, (4) enhancements to provide robust global communications, rapid adaptive command and control and mission pre-planning systems, (5) realistic exercise of the entire planning and decision making process including the involvement of the principals, and (6) enhanced capabilities to rapidly deliver, support and extract special operations forces from long distances.

The Task Force notes that the deployment of global range, conventional ballistic missiles capable of striking fixed coordinates will neither be a watershed capability for the U.S., nor is it likely to

provide any lasting asymmetric capability for us. The Task Force believes that the U.S. instead should focus on capabilities that our adversaries cannot easily duplicate and that will provide multi-mission effectiveness against a wide range of situations, both fixed and transient.

Finally, because of virtually all of the findings above, the Task Force believes strongly that the current DoD focus on delivery platforms for Time Critical Strike needs to be balanced with a considerably increased focus on ISR, munitions, C3, SOF and exercises.

These findings have led to the following recommendations:

ISR: *Assign an appropriate Service or Joint Agency to lead, plan and execute a coordinated, integrated, multi-sensor ISR and BDA capability for missions characterized by the five analyzed in this study. Action: The Secretary of Defense (SECDEF) with Support from the Under Secretary of Defense for Intelligence (USD(I)), the Office of the Director of National Intelligence (ODNI), the Strategic Command (STRATCOM), and the Special Operations Command (SOCOM)*

Planning and Exercising: *Preplan and rehearse a wide variety of scenario responses across STRATCOM, the geographic Combatant Commands (COCOMs), SECDEF and the National Security Council/White House Military Office (NSC/WHMO). The President of the United States (POTUS) and his principals should be involved at least once a year and the planning/rehearsing should be integrated across all of the commands and agencies involved. Where practical, key allies should be involved as well. Action: Joint Staff/J3 (tasked by SECDEF) lead with support from the Under Secretary of Defense for Policy (USD(P)) and the Under Secretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)).*

Munitions: *USD(AT&L) take the lead in developing and deploying a substantial force of counter WMD and anti-personnel munitions. Support should be provided from the Defense Threat Reduction Agency (DTRA), the Defense Advanced Research Projects Agency (DARPA), SOCOM and special service components as required.*

Hardened Underground Facility Defeat: *USD(AT&L) commission a study as to the effectiveness of various classes of energetic weapons on poorly characterized underground facilities. USD(AT&L) should be supported by DTRA, DARPA, SOCOM, special service components and the Department of Energy (DOE), as required.*

Special Operations Forces (SOF): *SOCOM develop an enhanced lifter for assault teams and improved CAS. The objective should be to provide such capabilities by modification to existing commercial aircraft (fuselage and engines).*

Dynamic Fire Control: *USD(AT&L) lead, with support from USD(I), the Assistant Secretary of Defense (Networks & Information Integration) (ASD(NII)), STRATCOM, SOCOM and the regional COCOMs, evolve existing and planned C3 systems to provide a near real-time linkage of sensor network data, in-flight weapons and munitions and SOF assets and sensors.*

Air-Breathing Delivery Vehicles: *USD(AT&L), with support from the Air Force and DARPA, perform a study to evaluate the relative performance, cost and risk for a next generation remote, time critical, conventional strike capability based on loitering or penetrating unmanned air*

breathing weapons. The trade space of range, payload types (e.g. kinetic, IO, ISR) and mass, single multi-purpose platform vs. multiple special purpose platforms, on station time, and feasibility of modification of an existing capability should be fully explored. The study should be completed in one year and a program initiated based on its findings.

Integration and exercising of combined operations C3I: *Joint Staff/J39 and DNI lead, with STRATCOM, SOCOM, and the regional COCOMs support as required, integrate, exercise and rehearse remote, time critical strike operations across COCOMs and the IC. The objective should be to plan and provide rapid target characterization and effects based mission pre-planning for situations characteristic of those requiring rapid conventional response from strategic distances. Exercises should be conducted at least semi-annually.*

In summary, our analysis and recommendations for scenarios believed to require prompt global strike ended in highlighting two different domains:

1. Difficult to find, identify and trace, relocatable or mobile, time critical targets that require close-up ISR, maneuverable weapons, and possibly SOF.
2. Far less stressing long-range, fixed, time critical targets that require improved standoff ISR and weapons that can strike fixed coordinates. In the analysis, this latter domain was a much more limited set than Domain 1.

In both domains, the need for improved C2, a more rapid decision-making process, and some specialized munitions was evident.

With this in mind, the Task Force has recommended an investment scenario that, when added to legacy forces, will accomplish most of the objectives demanded by these two different domains. The summary of these recommendations is depicted in Figure 2.

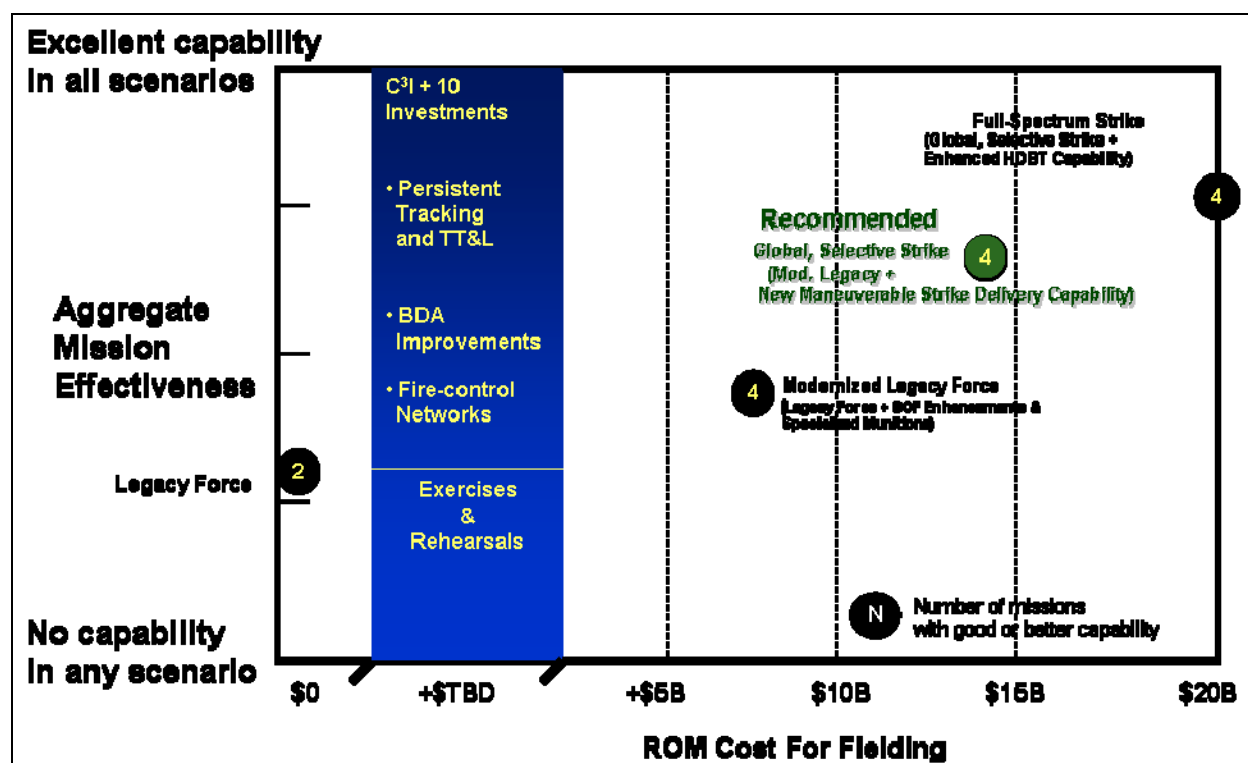


Figure 2: Investment Strategy

Figure 2 portrays the Task Force’s recommended investment strategy to achieve the greatest overall cumulative effectiveness against all five scenarios at the minimum cost. We see that although the legacy force has some capability across the five scenarios, it is only slightly above the 25% point in aggregate effectiveness and can provide a “Good” or better capability against only two of the five scenarios. As the first step in improving the situation, the Task Force notes the requirement for a number of non-weapon “enablers,” as discussed in the Findings and Recommendations. These are indicated in the blue box at the left of the figure. These are critically important to the effectiveness of the rapid conventional strike mission and should take priority over platform improvements in the short term. We have not attempted to provide a cost for these improvements, some of which will be significant and others less so. We believe, however, that the cost associated with these ISR and C3I enhancements will be at least of the same order of magnitude as the two strike capability builds recommended below. We also believe that the utility of these recommended ISR and C3I investments will apply and leverage other capabilities far beyond the time critical conventional strike missions which were the subject of this study. Similarly we note that the investments we have specifically recommended for the time critical conventional strike mission will also have significant utility in many conventional and asymmetric missions.

The first build in weapon capabilities we estimate at about \$7 Billion. This build consists of two separate capability enhancements to modernize certain aspects of the legacy force – improving the rapid insertion and extraction capabilities for Special Operations Teams and providing enhanced munitions capabilities.

The next build of capability, estimated at about an additional \$7 Billion, adds a new strike delivery platform(s) to the Modernized Legacy Force that can penetrate hostile environments and rapidly strike relocatable or moving targets.

The last step in the capability progression would be to add the ability to defeat a poorly characterized HDBT facility. The Task Force does not recommend moving to this final capability in the near future. Rather, we recommended continued research on ways to defeat this threat, preferably using innovative non-nuclear mechanisms.

Appendix A contains the Terms of Reference for this study.

Appendix B includes a list the Task Force Membership.

Appendix C provides a list of all of the briefings the Task Force received during the course of its investigations.

Appendix D is a tutorial discussing all of the potential capabilities and technologies considered by the Task Force. It is provided as background for the reader who may want a broader understanding of the technical issues underlying the various options analyzed in this study. These include: Ballistic Missiles, Cruise Missiles, Directed Energy, Special Operations, ISR, Information Operations, C3, and Intercontinental Gun.

Appendix E is a more detailed explanation of each of the five scenarios used by the Task Force in its analyses.

Appendix F offers a description of the current development programs or operational systems of record.

Appendix G is a list of acronyms used in this report.

CHAPTER I. BACKGROUND

PREVIOUS STUDIES AND CURRENT CAPABILITIES

A review of previous substantive studies dealing directly or to a significant degree with the issue of standoff strike is instructive in terms of identifying the enduring problems and focusing on solutions that so far have eluded discovery.

The 1997 Defense Science Board (DSB) Summer Study focused on the issue of *DoD Responses to Transnational Threats*.² While the 1997 study focused on different aspects of the problem than the work of this Task Force, the underlying issues of dealing with transnational threats including WMD framed the work of both panels. It is worthwhile to take a quick look at the findings presented in the 1997 study and assess how those have or have not changed in the intervening period.

That study made recommendations binned across six key elements:

1. Treat transnational threats as a major DoD mission
2. Use the existing national security structure and processes
3. Define an end to end operational concept and system of systems structure
4. Provide an interactive global information system on transnational threats
5. Address needs that have long been viewed as “too hard”
6. Leverage worldwide force protection and civil protection

Among the detailed recommendations were some that bore directly on the work of this panel and in some cases were part of the framing scenarios. The need to render safe nuclear devices that fall into the hands of rouge state or non-state actors was singled out as a needed capability to include the delivery of high velocity metal rods or other projectiles that could safely prevent detonation. Coupled with this was a requirement to increase research and development (R&D) on remote surveillance devices that could provide critical early warning for clandestine operations leading to detonation. Other areas of concern to the 1997 Summer Study included U.S. vulnerability to Information Operations (IO), a concern the remains valid today and which will be discussed later. Warning for biological and chemical attack was of grave concern in 1997 and remains today. While the focus of the previous panel was on sensing an attack underway, there remains an equally large issue today in terms of developing trigger points during an adversary’s planning phase.

One of the primary recommendations of the 1997 Summer Study was the need to establish clear lines of responsibility for transnational issues such as counter proliferation, combating WMD, counter terrorism, and information warfare. DoD and the Intelligence community have made significant progress on those recommendations in the intervening years although much work is still in progress.

² See Defense Science Board, <<http://www.acq.osd.mil/dsb/reports.htm#1997>>.

Fives years after the Transnational Threats Study, *The 2002 Nuclear Posture Review* (NPR) looked at several issues germane to this study as well. The “New Triad” created the need for additional conventional strike capabilities to provide not only intervention and retaliation options but provide deterrence as well. The report from the NPR concluded that nuclear weapons no longer provided deterrence in today’s world. Development of a non-nuclear pre-emptive strike capability was seen as providing the path to establishing credible deterrence for the varied adversaries faced by the nation. This expanded capability would come from a mix of kinetic weapons, information operations and directed energy weapons. Additionally the report detailed specific needs for improved command and control functionality, significant improvements in intelligence and expanded collection capabilities.

In the course of carrying out our investigation into the issue of *time critical strike from strategic standoff*, this Task Force heard from many of the same communities addressed in the NPR. For the most part, the NPR recommendations remain valid and needed. Some weapon technologies assumed to be closer to maturity have proven not to be as detailed further in this report (see appendix on currently operational systems and current development programs). The need for expanded and finer granularity of intelligence is key to the current task including defeating hardened and deeply buried targets as well as mobile and fleeing targets. This, coupled with an improved command/control infrastructure that allows for timely development of an operational plan to attack the target, along with obtaining the necessary strike authorities, are all critical components to successfully executing a prompt conventional operation.

Similar issues were echoed again in the 2004 DSB study on *Future Strategic Strike Forces*.³ While the 2004 Task Force target list overlapped only partially with that of this study, their findings and recommendations followed closely the findings of this Task Force. Command and control was deemed a major need area in order to support a “netted, collaborative strategic strike network.” Their findings on ISR went beyond the others in that it discussed the special needs for battle damage assessment (aka effects based assessment) and went on to task out the development of new close in sensors to augment current collection methods in hopes of overcoming deception practices and providing for positive confirmation that a target has been successfully prosecuted. The approach of the 2004 Study was to call for ISR to be viewed and acquired as a system. The study also addressed delivery systems and payloads citing the need for a quick long range delivery capability coupled with sophisticated payloads to include those of assistance to Special Forces. The following gaps were noted in the 2004 study:

- Promptness: need to strike 300 to 400 targets promptly. *As discussed below, this study addressed a much more limited number of “strategic.”*
- Accuracy: need to increase absolute accuracy to provide significantly improved weapon delivery capabilities. *Significant improvements have been made partially as a result of the 2001 DSB Summer Study on Precision Targeting.*
- Strike Options: Limited options for the President, many look unusable. *This is still valid, and is motivation for the current DSB Task Force.*
- ISR: Improved ISR single most important factor. *This is still valid.*

³ See Defense Science Board, <<http://www.acq.osd.mil/dsb/reports/fssf.pdf>>.

- Operational Effects assessment: BDA as it exists does not provide the information necessary for strategic strike assessment. *This is still valid.*

The 2004 study went on to recommend development of a combined long range ISR/Strike Air Weapon System to address some of the gaps along with conventional ballistic missiles.

ABOUT THIS STUDY'S TERMS OF REFERENCE (TOR)

Given this background and foundation, the Defense Science Board Task Force on Time Critical Conventional Strike from Strategic Standoff was requested by USD(AT&L) in November 2006 (see Appendix A), to evaluate a broader set of potential conventional strike capabilities with combined attributes of precision, rapid response, prompt and accurate battle damage assessment without the benefit of U.S. forces present in the immediate area or when local access is severely restricted, and for a very small number of targets (in contrast to the hundreds considered by 2004 study).

Each capability (acting solo or in concert with other capabilities) was to address a wide range of operational scenarios and acquisition factors, to include: target set, strike basing, delivery range, time from authorization to strike to target impact, need for preparation (get ready) time, degree of precision including impact of collateral damage, degree of blue force exposure, cost of ownership, marginal cost per kill, development time and development risk, and plausible mission scenarios as a context for evaluation. The study was expected to evaluate a complete range of selectable options within each scenario; to include the possibility that increasing intelligence capabilities will provide adequate cueing and warning time to allow timely positioning of current or future tactical assets in order to accomplish many realistic missions.

Supporting technologies as well as command and control, cueing, and warning procedures to enable such capabilities, including both the strike component as well as the supporting ISR component, are either available today or are in development —requiring for this study a range of assumptions on these enablers, and requiring inquiry into issues/organizations that are complex, highly interrelated and span multiple services, as well as operational and technological disciplines.

As a goal, the Task Force was requested to make recommendations on the basis of:

- 1) minimum acquisition cost and near term actions required to initiate development;
- 2) minimum development risk and near term actions required to initiate development;
- 3) operational flexibility near term actions required to initiate development; and
- 4) preferred approach based on the Task Force's judgment when considering all of the competing pros and cons of the various alternatives.

Threat, mission and capability performance parameters include:

- Target set: Soft vehicles and individuals in the open to hardened facilities, some of which are defended and a part of a networked shell-game.

- Accuracy: Sub-meter to 10 meters, but the relevance of which depends on character of the target and mission objectives.
- Basing: CONUS, OCONUS, Surface, Sub-Surface, Air, Space for both the ISR and weapon.
- Kill/Damage/Disruption Mechanism: Kinetic or directed energy (DE), with signatures that enable effects assessment. In addition, the kill mechanism should evaluate a timeline and pre-enabling techniques which either enable or enhance the kill mechanism, and magazine or reload capability to enable rapid firing.

Strike capability measures of effectiveness for comparisons include:

- Time to strike for particular implementation/execution, ISR and strike demands of a given target type to achieve and assess a high probability of kill. For moving or fleeting targets, also consider the surety and persistence of the supporting ISR concept and the inherent tradeoff between tracking/ID persistence and the time criticality of the strike response for two distinct scenarios – one in which sufficient tension and warning time is present to move assets into preparatory positions and one for no warning time.
- Rough Order of Magnitude (ROM) cost for both development and procurement for 24/7 availability anywhere within the world temperate zones, noting dependence upon other assets that may be available from other missions.
- Development risk for assembling and integrating the entire end-to-end capability using DoD TRLs for the enabling technologies and an independent assessment of the integration risk.

This issue and its associated problems and solutions carry with it a host of other considerations dealing with national and international policy and treaties. Strategic communication is a critical enabler and goes hand in hand with any strike capability considered. While this study's focus did not include evaluating those issues, the Task Force was mindful of the impacts as it assessed the relative merits of proposed solutions.

CHAPTER II. FINDINGS AND RECOMMENDATIONS

For access to the full report contact the Defense Science Board office at 703-571-0081.

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APPENDIX A. TERMS OF REFERENCE



ACQUISITION,
TECHNOLOGY
AND LOGISTICS

THE UNDER SECRETARY OF DEFENSE

3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

NOV 30 2006

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference -- Defense Science Board (DSB) Task Force on Time-Critical Conventional Strike from Strategic Standoff

Recent DSB and other government studies, as well as operational experience, have highlighted the need for the United States to have, within its options, the ability to strike with responsive conventional means when situations warrant. In many instances, precision and rapid response coupled with prompt and accurate battle damage assessment are the principal attributes required, even when U.S. forces are not present in the immediate area or when local access is severely restricted. Such a conventional capability -- characterized by rapidity of response, a high degree of precision and execution from afar -- does not exist today.

The technologies and C2 procedures to enable such a capability, including both the strike component as well as the supporting ISR component, are either available today or are in development. However, selecting the appropriate alternative to pursue involves establishing a number of tradeoffs and assessing the relative importance among many issues, including at a minimum, target set, strike basing, delivery range, time from authorization to strike to target impact, need for preparation (get ready) time, degree of precision, degree of blue force exposure, cost of ownership, marginal cost per kill, development time, and development risk. The study should seek to evaluate a complete range of options within several realistic scenarios. For example, it may be possible that increasing intelligence capabilities will provide adequate cueing and warning time to allow timely positioning of current or future tactical assets in order to accomplish many realistic missions.

These issues are complex, highly interrelated and span multiple services, as well as operational and technological disciplines. Accordingly, you are requested to establish a DSB Task Force on Time-Critical Conventional Strike from Strategic Standoff to explore and illuminate the various attributes associated with the different means of accomplishing such a capability. Parameters of Interest include:

1. Target set: Soft vehicles and individuals in the open to hardened facilities, some of which are defended and a part of a networked shell-game



2. Accuracy: Sub-meter to 10 meters, but the relevance of which depends on character of the target

3. Basing: CONUS, OCONUS, Surface, Sub-Surface, Air, Space for both the ISR and weapon

4. Kill Mechanism: Kinetic or DE, with signatures related to combat assessment. In addition, the kill mechanism should evaluate a timeline and pre-enabling techniques that either enable or enhance the kill mechanism, and magazine or reload capability to enable rapid firing.

As a function of the various alternatives being investigated, the Task Force should assess each alternative using four principal measures of effectiveness:

1. Time to strike: This should be examined not only as a function of a particular implementation concept, but also as a function of the ISR and strike demands of a given target type to achieve and assess a high probability of kill. In terms of moving or fleeting targets, this high probability of kill must also consider the surety and persistence of the supporting ISR concept and the inherent tradeoff between tracking/ID persistence and the time criticality of the strike response. Time to strike will be examined within the context of two distinct scenarios -- one in which sufficient tension and warning time is present to move assets into preparatory positions and one in which no warning time is available.

2. Cost: Rough Order of Magnitude for both development and procurement for 24/7 availability anywhere within the world temperate zones. Dependence upon other assets that may be available from other missions will be noted.

3. Development Risk: An assessment will be made of the development risk for assembling and integrating the entire end-to-end capability using DoD TRLs for the enabling technologies and an independent assessment of the integration risk.

4. Other: Any special requirements associated with a particular alternative should be noted here. These might take the form of policy issues, current treaty prohibitions, special training requirements, capabilities for peace-time practice and exercise, etc.

While the illumination of these tradeoff issues is the most important output product of the DSB study, it would be useful as well if the Task Force would include within its findings four specific recommendations:

1. A preferred approach if minimum acquisition cost were the dominant requirement and the near-term actions required to initiate development.

2. A preferred approach if minimum development risk were the dominant requirement and the near-term actions required to initiate development.

3. A preferred approach if operational flexibility were the dominant requirement and the near-term actions required to initiate development.

4. A preferred approach based on the Task Force's judgment when considering all of the competing pros and cons of the various alternatives and the near-term actions required to initiate development.

The study will be sponsored by me as the Under Secretary of Defense for Acquisition, Technology and Logistics, Under Secretary of Defense for Intelligence, Director, Defense Research and Engineering, and the Deputy Under Secretary of Defense (Acquisition and Technology). Mr. Bob Stein and Dr. Ron Kerber will serve as the Task Force Chairmen. Mr. Greg Hulcher and Mr. John Tuley will serve as Co-Executive Secretaries, and Mr. Andrew Chappell will serve as the Defense Science Board Secretariat representative.

The Task Force will operate in accordance with the provisions of P.L. 92-463, the "Federal Advisory Committee Act," and DoD Directive 5105.4, the "DoD Federal Advisory Committee Management Program." It is not anticipated that this Task Force will need to go into any "particular matters" within the meaning of title 18, United States Code, section 208, nor will it cause any member to be placed in the position of acting as a procurement official.



Kenneth J. Krieg

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APPENDIX B. TASK FORCE MEMBERSHIP

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Mr. Robert Stein, *Private Consultant*

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Mr. Greg Hulcher, *OSD*

Mr. John Tuley, *NGA*

TASK FORCE MEMBERS

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Mr. Dennis Keane, *MIT*

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ADM (ret) Richard Mies, *SAIC*

Mr. Robert Moore, *Private Consultant*

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Mr. Andrew Chappell, *Defense Science Board*

SUPPORT STAFF

Ms. Michelle Ashley, *SAIC*

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Ms. Amely Moore, *SAIC*

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APPENDIX C. BRIEFINGS RECEIVED

October 23-24 2006

Mr. Doug Bruder	DTRA	DTRA Overview
LtCol Warren Hines	STRATCOM	Threat Assessment/Strike Mission Objectives
Mr. Greg Hulcher	OSD	TOR Overview/Assessment of Standoff Weapons
Ms. Judy Kim	DoD OGC	Ethics Overview
Dr. David Stoudt	Navy	Directed Energy
Mr. John Wilcox	AT&L	Discussions of Current/Future Stand-off Strike Programs

November 28 – 29 2006

Col Bryan Bartels	STRATCOM	Global C2 Development, Collaboration, Integration and Synchronization
LT CMDR Andrew Biehn	PMA 21	Naval Standoff Strike Planning and Execution
Mr. Ed Jackanowski	ASN(RD&A) Air	Navy Programs of Record and Potential Emerging Systems/Variants
CAPT Robin Myers	JCS/J2T	Targeting Cycle Gaps Affecting Time Sensitive Conventional Strike
Maj Doug Roth	SAF/AQP	Air Force Programs of Record and Potential Emerging Systems/Variants
Mr. Robert Thomas	NGA	Meeting the Need for Rapid Precision from ISR Assets

January 18 – 19 2007

Col Paul Gydesen	USAF	USAF ICBM, Ballistic Missile – Prompt Global Strike
Dr. Barry Hannah	Navy Strategic Program Office	Navy CTM, SRBM, IRBM
CDR Frank Whitworth	CENTCOM	Issues with TCCS from Current Ops Experience
Dr. Ellen Williams	University of Maryland	MITRE/JASON Study

February 15 – 16 2007

Mr. Paul Bavitz	Lockheed Martin	Strike Concepts and Approaches
Ms. Camilla Gean	Army	Army Hypersonic Briefing
Mr. Robert Haffa	Northrop Grumman	Time Critical Strike
Mr. Steve Morrow	Boeing Corporation	Time Critical Conventional Strike
		Special Capabilities for TCCS from
MG Dave Scott	SOCOM	SS scenarios
Ms. Heidi Shyu	Raytheon	Time Critical Conventional Strike

March 22 – 23 2007

Mr. Greg Hulcher	OSD	Update on Expected Strike Timelines
		DTRA Presentation of Defeating
Dr. Pat McCreary	DTRA	WMD
Dr. A. Fenner Milton	Army	Army Vision Lab Steel Rain
Gen (ret) Glenn Otis	Army	Directed Energy Briefing

April 18 – 19 2007

Mr. Dennis Evans	OSD PA&E	PA&E Missile Cost Analysis Study
Dr. Dana Johnson	Northrop Grumman	Information Operations
	D/NIO	
Mr. Jim Knittle	WMD/Proliferation	Weapons of Mass Destruction
LT Calvin Nobles & Mr.		
Michael Zanski	NSA	NSA – Sensitive Targeting
		Directed Energy Solutions for
		Offensive Strike of Time Critical
Mr. Joseph Paranto	Boeing	Targets

APPENDIX D. STRIKE OPTIONS TUTORIAL

BALLISTIC MISSILES

The most mature option for prompt, long-range, conventional strike is the ballistic missile, which has been the backbone of the Nation's strategic nuclear deterrent for over 50 years. However, all the currently deployed intercontinental ballistic missile systems (ICBMs) – the land-based Minuteman III operated by the Air Force and the Navy's submarine-launched Trident II – are only configured to deliver nuclear warheads (or inert ballistic reentry warheads for test flight purposes). Building on the legacy of these weapon systems provides a relatively low-risk path to a conventional weapon system with global reach. Table D-1 summarizes the principal advantages and disadvantages of conventional ballistic missiles for the time-critical, standoff strike mission.

Advantages	Disadvantages
Global reach with shortest flight time.	Relatively small payload capacity (compared to a bomber).
Proven, mature technology for attacking fixed, well-located targets.	Not easily adapted to mobile targets or those that relocate within missile flight time.
Potential to leverage cost-effectively existing nuclear deterrent infrastructure, particularly for submarine basing.	Potential for attack ambiguity with peer competitors.
Difficult to defend against – essentially assured access.	Existing treaties limit some basing/deployment options.
No exposure of personnel to enemy harm.	Recall not possible; but abort may be feasible.

Table D-1. Characteristics of Ballistic Missiles for Time Critical, Standoff Strike

While short flight time is a key advantage of ballistic missiles, longer standoff ranges increase the flight time required to get the missile to the target. For example, the flight time on a minimum energy trajectory at a range of 3300 Km is about 15 minutes whereas at a range of 6700 Km its 25 minutes. If the missile has sufficient energy at a given range to the target, its trajectory may be tailored for various reentry conditions and flight times. Table D-2 shows nominal flight times, reentry angles, and velocities as a function of variations in ballistic trajectories for a nominal range of 6700 Km (~ 3650 nm).

Trajectory Type	Range (Km)	Reentry Flight Path Angle (Degrees)	Reentry Velocity (Meters/sec)	Time of Flight (Minutes)
High Loft	6700	-50	7000	42
Minimum Energy	6700	-30	6400	25
Depressed	6700	-10	7000	17

Table D-2. Characteristics of Various Ballistic Missile Trajectories

There are both technical and political/policy challenges that need to be addressed to develop a viable ballistic missile alternative for the time-critical, standoff strike mission. The key technical issues are associated with the terminal delivery vehicle, the warhead, and the accuracy of the guidance system. All these technical issues are interrelated. For example, the lethal effectiveness of a particular warhead kill mechanism against a specific target will impose requirements on the delivery vehicle, likely in terms of terminal velocity and impact angle, and on the guidance in terms of an accuracy specification.

The primary policy/political issues revolve around concerns about basing alternatives, ambiguity or mistaken intent if the system is used, and unintended consequences. Evaluation of alternate basing options will involve assessing prelaunch survivability and overflight of the U.S., its allies, or neutral/uninvolved territory with the associated issue of where the booster stages will land. There will also be some potential concerns about accidental launch, if both nuclear and conventional weapons are at the same basing location. Some basing alternatives are restricted by current treaty agreements, including the Strategic Arms Reduction Treaty (START) and the Intermediate-Range Nuclear Forces (INF) Treaty. Each of these issues will be discussed in the following sections.

Technical Issues

Existing nuclear ballistic missiles consist of stacked rocket engines, typically powered by solid fuel, that boost a warhead and delivery vehicle(s) along a parabolic suborbital trajectory for eventual reentry into the atmosphere to hit the target. Booster propellant is a mature technology; however, to maximize range within a volume constrained submarine launched missile, a more energetic class 1.1 propellant is used. Almost all other solid fuel missiles rely on less energetic and less volatile class 1.3 propellant (the AF Peacekeeper had a class 1.1 upper stage). Although more energetic, class 1.1 propellant has more handling issues that make the submarine basing mission, essentially, its only application. The major design trade at the missile system level is between booster size, range, and the weight of the warhead. At intercontinental ranges, the missile generally uses three booster stages, a smaller post-boost vehicle (PBV), and a precise guidance system to deploy the reentry vehicle(s) on a trajectory that will hit the target. Guidance corrections are made up to the end of powered flight by using small reaction jets on the PBV. The reentry vehicle(s) are then carefully deployed from the PBV and thereafter travel on an unguided ballistic trajectory to the target. Considering that most of the flight is ballistic and unguided, the on-target accuracy achieved is remarkable and certainly sufficient for their nuclear payload to be effective. However, for the conventional strike mission, improvements to current nuclear ballistic missile technology are required with respect to the reentry vehicle, the warhead, and the guidance system accuracy.

Reentry vehicle – To achieve the increased accuracy required for some of the candidate warheads to be effective, it may be necessary to remove the reentry errors associated with traditional ballistic reentry systems. In addition to pure ballistic reentry, the study panel reviewed developments in error correcting, maneuvering and boost-glide delivery system options.

A ballistic reentry vehicle approach is technically the simplest since the technology is mature and in use. However, with no guidance and control during reentry, vehicle dispersions from the desired trajectory are likely due to wind, weather, and vehicle heat shield ablation effects. The

accuracy degradation from these error sources would be unacceptable for most conventional warheads.

An obvious solution to this problem is to provide some means to navigate, guide, and control the vehicle during reentry. A relatively straightforward control approach would be to add a modest “error correcting” capability to the vehicle such as movable flaps or a jet reaction system. Figure D-3 depicts the reentry vehicle’s guidance, navigation, and control (GN&C) loop. The technical issues relating to achieving high accuracy will be discussed in a later section.

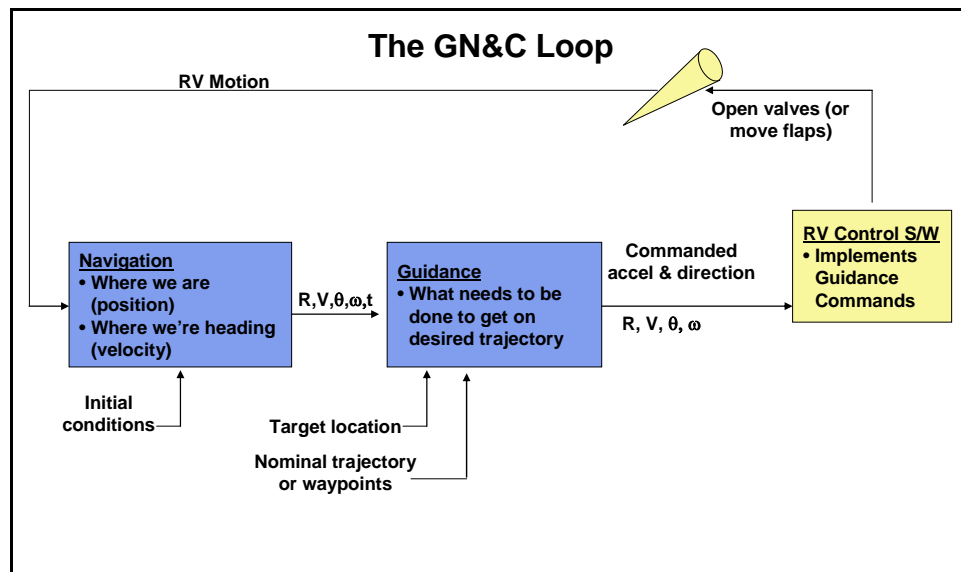


Figure D-3. Reentry Vehicle GN&C Loop

For a number of reasons, such as warhead delivery constraints, simply guiding the reentry vehicle to the target using an error correcting control scheme will not always be sufficient. It may be necessary to shape the reentry trajectory in order to produce a required set of terminal conditions at or near impact and to satisfy other en route and flyout constraints. To do this will likely require the reentry vehicle to have a much higher maneuver capability (high lift-to-drag (L/D) ratio). Such “glide” vehicle designs are being studied and tested. In the extreme are boost-glide vehicle concepts wherein a very high L/D design is envisioned. These vehicles are intended to glide hypersonically over thousands of miles in the upper atmosphere, almost like the Space Shuttle during reentry, following a fairly short boost phase to get up to a sufficient speed and altitude.

Over the last 30 years, all the Services, as well as NASA, have conducted periodic technology development projects to explore various reentry vehicle designs. The feasibility of error correcting, maneuvering and boost-glide concepts have all been proven. Examples include: (1) early Navy testing of the Mk-500 Evader, and much more recently, test flights of the Enhanced Effectiveness (E^2) and Life Extension Test Bed (LETB) error correcting RB's; (2) Air Force flight tests of the Advanced Maneuvering RV (AMaRV) in the early 1980's; (3) Army Pershing I and II systems (pre-INF Treaty); (4) testing of the DOE/Sandia Winged Energetic RV Experiment (SWERVE) in the early/mid 1980's; and (5) several NASA flight test programs of various entry vehicle configurations. While further development is required for almost all options, the most significant remaining technical issue is a thermal protection system (TPS) that

can sustain the heating loads of the most aggressive (in terms of range and atmospheric flight time) maneuvering and boost-glide designs. Current TPS technology with this capability is both heavy and bulky (i.e. the Space Shuttle tiles) and unlikely to be used in this application. Other existing TPS technology used in the past for ballistic RV's (e.g. carbon-carbon, wrapped carbon phenolic, etc.) would need to be thicker than that used for ballistic RV's to allow for glide times of several minutes, and would require yet more technology development and probably new materials for glide times well in excess of about 10 minutes – especially for the nose tip, flaps, fins, and any other leading edges.

Warheads – Depending on the target characteristics, there are a range of warhead options for the conventional strike mission including: flechettes, submunitions, earth penetrators, and inert mass delivered at high velocity. Additionally, future payloads could be delivered by unmanned aerial vehicles (UAVs) that might provide an intelligence, surveillance, reconnaissance (ISR) or battle damage assessment (BDA) capability.

Each payload or warhead option brings its own constraints on terminal or impact conditions. Flechettes are small, dense rods that would be expelled from a vehicle at an optimum range shortly before reaching the target. They spread out in a shotgun-like pattern and impact the target at very high velocity. A fuse would be employed to split the vehicle open at an optimum time to control how far these rods would spread out (i.e., controls the pattern size and therefore density). It is usually desired to have as high an impact velocity for the flechettes as possible and this warhead would be suitable for use in a simple error-correcting type vehicle.

Similarly, if the warhead were just an inert mass, the goal would be to hit the target with as high a velocity as possible to maximize the kinetic energy delivered. Again, an error-correcting vehicle could suffice.

With submunitions and penetrators, higher L/D vehicles would be required because the terminal constraints are much more restrictive. Delivery of (existing) submunitions (or UAVs) would require the vehicle to slow down (to near Mach 1) and fly nearly horizontal as a bomber might do when dropping bombs or submunitions. For an earth penetrator, required impact conditions would demand a dive near vertically onto the target with a small angle of attack to avoid ricocheting off the ground. Terminal speed must be 3500-4000 fps to prevent breakup of the penetrator as it enters into a hydrodynamic regime where it actually becomes a plasma and erodes during penetration.

Guidance accuracy – The guidance systems for nuclear ballistic missiles rely on very precise inertial navigation systems, and in some cases, on stellar sensor attitude updates. The reasoning here is that, in a nuclear exchange, it is not prudent to rely on external aids that may not reliably be available. Current nuclear ballistic missile systems have demonstrated outstanding accuracy for self-contained inertial navigation that is certainly sufficient for its mission requirements. However, as discussed above, this accuracy may not be adequate for conventional warheads.

The most attractive alternative for providing the improved accuracy required by the conventional ballistic missile application is to aid the inertial sensors with position and velocity measurements from the Global Positioning System (GPS), but the high velocities and rapid decelerations of the reentry environment present unique technical problems for GPS. Specifically, the high reentry

speeds will induce a plasma sheath around the reentry vehicle that blocks the onboard GPS receiver from getting signals from the satellites. (It should be noted that plasma blackout is not an issue for every time-critical concept or mission. For example, the boost-glide vehicles discussed above are hypersonic, high L/D configurations that, after a short boost phase to get them up to a proper altitude and speed, spend the majority of their flight gliding at 100-150 kft and speeds of Mach 10-12. Under these flight conditions, plasma will most likely not be an issue.)

For high-accuracy situations, it will be necessary to reacquire GPS after the reentry vehicle has slowed and the plasma has dissipated. There are several potential solutions to the plasma problem, and some or all could be used together:

1. Attempt to suppress plasma by injecting a substance, such as Freon, into the reentry vehicle/reentry body (RV/RB) wake. This has been tried by the Navy with inconclusive results.
2. Use a deeply integrated (DI) Inertial Navigation System with GPS (INS/GPS) to attempt to maintain tracking even through plasma. This has not been flight tested, but merits some analysis and lab testing.
3. Try to shape the reentry trajectory to allow for sufficient time to reacquire GPS post-plasma (or avoid it altogether). The success of this depends on vehicle flight characteristics (L/D).

None of the solutions have been thoroughly validated by demonstration flight testing, although there are relevant experiments in both the Navy and Air Force technology programs over the last 25 years.

In cases where we attempt to maintain or reacquire GPS, it will be necessary to have high-g (and jerk) GPS tracking capability (i.e., inertial measurement unit (IMU) aiding of the GPS track loops will be needed) and a GPS antenna system with essentially “full sky” coverage. In general, one can consider three classes of reentry “end game” trajectories: (1) error correcting or “straight in,” (2) penetrator delivery, and (3) submunition dispensing. The latter two types of trajectories are depicted in Figure D-4 for a “typical” maneuvering RV/RB with an L/D ~ 1. It is instructive to examine the end game, or post-plasma portion, of these trajectories to get a feel for what the GPS reacquisition environment may look like. An earth-penetrator type trajectory, for example, would certainly require very good accuracy and therefore likely necessitate GPS reacquisition. Its post plasma trajectory is characterized by very high g’s (50 – 100), high levels of jerk (> 25 g/sec), and high angular rates.

The only alternatives to providing the required accuracy for the most stressing conventional strike missions without solving the GPS post-plasma acquisition problem are:

1. Employ some type of terminal sensor to obtain good accuracy in the terminal area. This would likely be expensive, heavy, and brings a host of other potential problems such as target signature temporal stability.

2. Use a very accurate IMU (with good alignment – possibly achieved by use of gimbals or a stellar sensor) to mitigate accuracy degradation from the loss of GPS from plasma blackout to target impact.

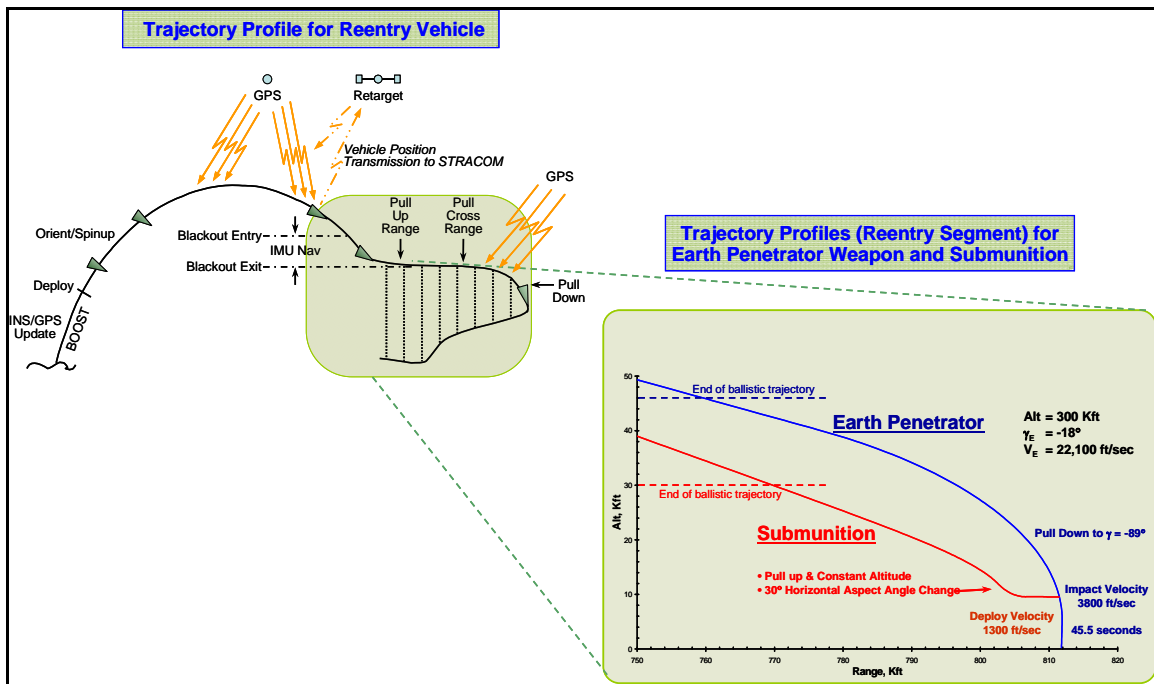


Figure D-4. Trajectory Shaping to Address GPS Plasma Issues

Policy/Political Issues

The primary policy/political issues revolve around concerns about basing alternatives, ambiguity or mistaken intent if the system is used, and unintended consequences.

Basing – The options for basing a CBM include sea-based (on submarines or possibly ships), land-based (likely in silos) in the continental U.S. (CONUS), forward-based (likely on transportable launchers or simple “milk stools”) in the U.S. or allied territory, and air-launched with the carrier aircraft stationed either in the U.S. or in the theatre. With the exception of the air-launched option, there are no significant technical challenges with the basing options since all are in use today or have been used in the past. Evaluation of alternate basing options will assess prelaunch survivability, overflight of the U.S., allied or neutral/uninvolved territory with the associated issue of where the booster stages will land.

The submarine basing alternative is the most flexible since, with the world’s major oceans as patrol areas, there are no access concerns, and submarines can be positioned (either a priori or as a conflict escalates) to provide trajectory options that avoid flying over any sensitive areas. It is also likely that the trajectories can be planned so that the booster stages (certainly the first and second stages) will fall safely into the ocean. Third-stage fallout for any basing mode will be a problem that needs to be addressed since, except for highly maneuverable RVs, it will likely fall into the target area. While prelaunch security is not expected to be a major issue for any basing option, the stealth of a submerged launch vehicle provides the greatest possible security. Finally, since the Navy proposes using the existing Trident SSBN and/or SSGN for the conventional

strike missile, this basing option is cost-effective because of the ability to leverage the infrastructure already in place for the strategic nuclear deterrent. This dual basing (in the case of an SSBN) raises some issues about the accidental launch of a nuclear weapon, but the U.S. has deployed “mixed loads” in previous situations, such as during routine flight tests. Further, the Navy has suggested systems and procedures to address this problem that are derived from their current operational test program where test launches of inert reentry vehicles are made from submarines that are also carrying nuclear missiles. Consequently, the study concluded that mixed-load deployments do not present any unsolvable problems.

Surface ship basing is currently prohibited under START (for ranges exceeding 600 km). However, the current START accord will expire in 2009 unless it is renewed. This basing option provides nearly all the characteristics of submarine basing except stealth. It would require the development of a ship based ballistic missile and possibly a new launch system.

Land basing in CONUS presents the challenge of potentially flying over populated U.S. territory. This issue can be mitigated if the missiles are based in coastal areas. However, there will still be the problem associated with flying over allied territory (which in many cases might be Canada). There are potential targeting issues with targets on the south side of mountains or other steep terrain when the missile is launched from CONUS. The trajectories also may be difficult to plan so that the booster stages land in acceptable regions. Increased maneuver capacity, such as with boost-glide reentry vehicles, provides the greatest flexibility for trajectory planning. The result of these issues may be a deterrent to using the weapon when it is needed. Some of the difficulties of land basing may be avoided by forward basing either in U.S. territory, such as Guam or Alaska, or with allies in various parts of the world. While there are no significant issues with U.S. territory, allied basing will likely present significant diplomatic challenges.

While air-launched ballistic missiles are not particularly difficult technically (the Pegasus satellite launch system provides a very relevant prototype), the weight limitation of air launch will almost certainly restrict either range or payload or both. If the air-based system range requires the aircraft to be in theatre with or near the target, this option may have response time limitations that make it less attractive than the alternatives. Also, if the aircraft needs to be dedicated to this system, this alternative may also be quite expensive.

Attack ambiguity – One of the most significant issues with conventional ballistic missiles is the concern that use of the weapon would be perceived as a nuclear attack. This issue has been a key concern of Congress relative to the Conventional Trident Modification, where a Trident D5 missile would be modified to carry a conventional warhead. While there are patrol options or basing locations that can minimize this issue, as long as either Trident D5 or Minuteman III missiles are used, there is a chance that peer competitors (who are likely the only ones able to detect a launch) might misinterpret U.S. intentions. One way to alleviate this concern is to design a new missile with a distinct boost signature that is clearly distinguishable from the missiles in the U.S. strategic nuclear deterrent. Another option might be to develop a boost-glide type weapon system.

In addition to launch phase signature ambiguity, there is the potential for radar signature ambiguity during either midcourse or the terminal phases of the mission. Radar signature ambiguity is more of an issue during midcourse since, as the reentry vehicle gets closer to the

target, the uninvolved nation should be able to resolve the trajectory data and determine that the weapon is not targeted at them. Detecting a ballistic missile launch requires sensors that are only likely to be available to peer competitors. Because of the mutual assured destruction concerns of a major nuclear exchange, peer competitors may be less likely to over react to a single ballistic missile until they are able to reliably determine its true destination.

Finally, there is the possibility of “notification of intent”. The U.S. could, as it does with test flights, notify various foreign parties of a planned launch. For a time critical mission, the notification time may be short, and, if there is concern about alerting the target, notification may not be desirable since it might compromise the mission.

Unintended consequences – During the Cold War, the U.S. and the Soviet Union entered into a number of treaties that limited both sides’ options for deploying CBMs. The two still in effect are summarized in Figure D-5.

These treaties were originally motivated by limiting U.S. and USSR risk to certain ballistic missile threats. Consequently, it is important to anticipate the impact of a U.S. decision to deploy a CBM on decisions other nations will make in response. With the proliferation of both short- and long-range ballistic missile technology in emerging nations, U.S. deployment of conventional ballistic missiles may result in new threats to which we would be exposed.

- **START**
 - Expires in 2009
 - Ship-launched ballistic missile max range = 600 km
 - Sub-launched ballistic missile max range = no limit
 - Counted as submarine-launched ballistic missile (SLBM) if over 600 km (includes SSGN)
 - Ship/sub-launched cruise missile max range = no limit
 - Air-launched ballistic missile max range = 600 km
 - Air-launched ballistic missile with lift max range = no limit
 - **INF Treaty**
 - No expiration date
 - Restricts ground launched ballistic missile range
 - Permitted range <500 km or >5500 km
 - > 5500 km counted as ICBM

Figure D-5. Treaties Pertaining to Ballistic Missiles

CRUISE MISSILES

This section provides a brief, unclassified discussion of cruise missiles. It contains a summary of the principal attributes; provides a history; describes the technologies and characteristics of cruise missiles; gives brief descriptions of the cruise missiles that have been developed over the years; discusses the possible future of cruise missiles; and concludes with potential improvements.

Summary of Cruise Missile Attributes

- Pilotless, air-breathing (sometimes rocket powered), continuously powered, usually relatively low flying, guided using aerodynamic lift and control throughout flight. Some cruise missiles (e.g., Tactical Tomahawk) have two way data links for missile status and retargeting.
- Payload is integrated as part of the airframe, with missile assumed destroyed at the end of the mission.
- Ranges can extend thousands of miles, with accuracies of tens of feet.
- Can be launched from land, sea surface and sub surface, and air.
- Payloads of conventional and nuclear warheads, other specialized cruise missile payloads considered, at least conceptually, include ISR systems/sensors and niche weapons concepts (non-kinetic weapons, penetrators for HDBT, etc.).
- Speeds can be sub- or supersonic. Typical flight times range from tens of minutes to several hours.

History

Cruise missiles were first conceptualized in about 1891 by Sir Hiram Maxim, the inventor of the modern machine gun and a dabbler in flying machines. The first example of a cruise missile was the Kettering Bug, commonly known as an aerial torpedo. It was an unmanned biplane that flew in a straight line for a set period of time, detached its wings and struck the ground with the fuselage and warhead. Developed during World War I, it integrated aircraft guidance technologies developed by Elmer and Lawrence Sperry for an U.S. Army project led by Charles F. Kettering. The first flights occurred in the fall of 1918, but it was never used in war as WWI came to an end that November.

Between World War I and World War II both the British and Americans continued aerial torpedo development. The first launch of a cruise missile (called Larynx) from a destroyer at sea occurred in the 1920s. Prototype aircraft with names such as Hoop-la (British), various versions of Mistel (German), and TDR-1 (American) appeared during WWII with varying results. These all appeared similar to manned airplanes of the day.

The first cruise missile used in war was the German V-1 flying bomb. The V-1 was used in raids against England beginning in June 1944. . It had the appearance of a modern day cruise missile with a bomb-like fuselage and short wings and fins. It was small and cheap and was made and used in very large numbers with effect. Powered by a pulse jet engine and guided by an inertial

guidance system, it flew at high speed and low altitude, and had a range of about 250, and later 400, kilometers (140 and 225 nm) with a warhead of 800 kilograms (1760 pounds). Initially launched using a steam catapult from ground ramps, V-1s initially had metal wings (later changed to wood) with no control surfaces; instead employing tail fins and a rudder for control. Gyroscopes kept it stable, a magnetic compass controlled direction, and a barometric altimeter controlled altitude. Powered after launch by a distinctive sounding pulse-jet engine, V-1's used either a timing or a distance-estimating system to lock the control surfaces and pop out spoilers, which would put the missile into a steep dive. The V-1 used an electric fuse, but had mechanical and time-delay fuses for backup. By today's standards, it was not accurate (it is believed half the V-1s fell roughly within four miles of the aim point), but it was accurate enough to spread terror in the city of London and the English countryside. The V-1 could be fitted with a nerve gas warhead, but this variant was never used. Other payloads did see some use: including 23 one-kilogram incendiary bomblets and a cardboard tube with propaganda leaflets. Toward the end of the war, some V-1s were launched from specially modified Heinkel He-111 bombers. At least 30,000 were built during the World War II.

Cruise Missile Technologies

The V-1 story provides a quick introduction to the technologies that make cruise missiles work. As the state of the art in these technologies evolved, the types used in cruise missiles changed. Key technologies that form the basic components of cruise missiles are described in more detail as follows:

- **Propulsion and fuel (for both launch and flight):** Most cruise missiles use a booster (usually a solid fuel rocket) for launch and a jet engine for sustained flight. The fuels used vary from one missile type to another.
- **Aerodynamics (bodies, wings, and control surfaces):** Nearly all cruise missiles use shapes and surfaces to maintain and control flight, as in manned aircraft.
- **Guidance and Navigation:** Today, most cruise missiles use some kind of INS, composed of gyros and accelerometers. Many modern cruise missiles employ an additional external data input to provide in-flight position updates to the INS to refine the navigator, thus significantly increasing the overall accuracy. Such data sources include updates from map or scene matching algorithms; in addition, nearly all modern cruise missiles use GPS for this purpose. Another external data source for navigation updates that is common to modern cruise missiles are altimeters (barometric, radar, and combined).
- **Communications:** As will be discussed later, several of today's cruise missiles use in-flight communications. Some allow the missile to report its status and many allow controllers to change some aspect of the mission being flown (including designating a new target).
- **Sensors:** Some cruise missiles carry sensors, primarily radars and cameras. These are used for navigation purposes or as ISR sensors.
- **Payloads (kinetic and non-kinetic) and fuses:** Most cruise missiles carry explosive warheads (conventional and nuclear), unitary bombs or smaller bomblets. Non-kinetic warhead concepts also exist, including biological and chemical constructs.

The fuse activates the warhead, and fuse types include contact fuses (sometimes with fixed or selectable time delays), timing fuses, altimeter fuses, and distance measuring fuses (as in the V-1).

Cruise Missile Characteristics

The primary characteristics of cruise missiles are provided below:

- Unmanned
- Speed and range: Although a few cruise missiles travel at more than the speed of sound, most are subsonic, usually high subsonic. Maximum ranges vary from a few 10s of miles to more than 1000 miles.
- Time of flight: Speed and range obviously combine to yield a time of flight to the target, which together with times for other links in the kill chain (ISR and C2 times) produces a total reaction time — the time it takes to search for, decide to strike, and hit a target. Most cruise missile flight times range from tens of minutes up to several hours (again dependent on speed and range to target).
- Flight Profile (altitude, maneuverability, etc.): Cruise missiles essentially are confined to altitudes of less than about 30,000 feet (although there are a few modern variants that can fly much higher during some portions of the flight profile). Many cruise missiles fly very close to the surface of the earth to avoid detection and try to “hug” the terrain.
- Part of a cruise missile flight profile can include a loiter interval; this can be used to reduce the response time by reducing the time of flight for an emergent or time sensitive target or to redirect the missile with updated target information. The message to transition from a loitering posture to striking the target (or to a new target) can come via communications from an external “controller” or from an organic sensor on the missile.
- Accuracy: Many cruise missiles are coordinate-seeking weapons, i.e., they guide to the geographic coordinates (latitude, longitude, and altitude, usually in GPS coordinates) provided to them. There are cruise missiles with organic seekers/sensors of some type for improved targeting. Some cruise missiles can also be provided real-time direction from a human (man-in-the-loop, or MITL) for designated targets. In general, accuracy has two contributing factors: target location error (TLE – not knowing *exactly* where the target is) and circular error probable (CEP – not being able to navigate and guide to the aimpoint, *exactly* where the target is believed to be). CEP has two components: Navigation, which is how well the missile knows where it really is (depends on the type and quality of the navigation system), and guidance, that is, how well the missile can guide to where it wants to be (depends on the maneuverability and controllability of the missile). Accuracy errors are associated with all three spatial dimensions.

For coordinate-seeking cruise missiles, GPS alone can produce accuracies with miss distances of several 10s of feet. Other update techniques can achieve improved

accuracies, especially approaches that combine INS with external sources such as GPS.

- **Launch platforms:** Cruise missiles can be launched from ships, submarines, aircraft, and land sites. Special launchers are often needed, although some submarines use normal torpedo tubes and some aircraft can use existing pylons. A system is required on the launch platform or near the launch point to transport, store, power up, and initialize the missile prior to launch.
- **Sensors:** Cruise missiles often have sensors associated with their navigation systems, including the TERCOM radars, DSMAC cameras, or other position update sensors. Tactical Tomahawk also uses the DSMAC camera to record battle damage indication images of previous strikes at preplanned locations as the missile flies over. Other sensors can include devices intended to detect, identify, locate, and sometimes home on the missile's target.
- **Reliability:** This is a measure of the probability that the cruise missile will successfully achieve the desired effect. Typically reliability is the cumulative probability of successful initialization, launch, flight, control, and warhead detonation. Reliability (and accuracy) are often used in determining numbers of missiles required to achieve an overall desired effect on a given target.

Cruise Missiles – Past, Present, and Future

The following is a brief discussion of cruise missile evolution after WWII. Immediately after the war, and even during the last stages of the war, the U.S. Air Force, the U.S. Navy and the Soviet military built their own cruise missiles based on the V-1, and the U.S. Army tried its own “flying wing” design. Most launches were from the ground, but air-launched, surface ship-launched and even submarine-launched cruise missiles were explored by the services.

Cruise Missiles from the 50s and 60s

From the late 1940s through the end of the 1960s, many efforts were made to develop guided missiles in general, and guided cruise missiles in particular. While these efforts made progress in understanding the key technical issues and maturing the required technologies, they did not succeed in producing a practical cruise missile. Most of these missile concepts were supersonic with ranges of up to several thousand miles (that consequently resulted in very large missile sizes and weights). Many of these early Cold War cruise missile concepts had significant challenges in flight control, guidance and navigation, and overall reliability. Early missiles and programs included the USAF's Matador, Mace, Snark, Hound Dog, Crossbow, Navaho, Buck Duck, Bull Goose, and Quail; and the USN's Regulus series, Rigel, and Triton.

Modern Cruise Missiles (from the 70s to the present)

By the late 1960s, the various key technologies required by cruise missiles had matured enough such that operationally useful cruise missiles became practical and affordable. These technologies included developments in improved accuracy of gyros and accelerometers and smaller, more powerful computers. With these advances, developments began in earnest of cruise missiles that became operational, and several remain in service today, as described as on the next page.

- Harpoon (AGM/RGM/UGM-84A) – USN/USAF. Air-, ship-, and sub-launched anti-ship cruise missile. It originally used a heading reference system and a radar seeker to find and guide to the target. Operational range was initially about 60 nm. Harpoon operational deployments started in 1977 and continue to this day.
- Tomahawk (RGM/UGM 109A/B/C/D/E) Sea-Launched Cruise Missile (SLCM) – US and UK navies. The A variant had a nuclear warhead for striking very distant land targets, and the B variant was an anti-ship missile (similar to Harpoon) with an operational range of about 250 nm. Neither are operational today. The C and E variants have large unitary warheads and the D variant has small bomblets that can be distributed over one or more areas. The E is called Tactical Tomahawk, which is less expensive and has, among other things, two-way communications, including redirection of the missile after launch. The C and E variants have ranges of about 900 nm. The Tomahawk series started in the early 1980s and continues to evolve today.
- ALCM (AGM-86A/B/C/D) Air-Launched Cruise Missile – USAF. The A and B variants had nuclear warheads, and the C and D are conventional (called CALCMs). The C has a unitary blast fragmentation warhead, and D has a penetrator warhead. The ranges are about 750 miles. Initially operated in the early 1980s, it remains operational today.
- ACM (AGM-129A/B) Advanced Cruise Missile – USAF. These air-launched cruise missiles have nuclear warheads, have longer range capability (1865 mi) than the ALCM and CALCM missiles, and use stealth technology.
- SLAM – ER (AGM-84K) Standoff Land Attack Missile-Expanded Response – This missile is an evolution of Harpoon (AGM-84A) and SLAM (AGM-84E). The SLAM – ER is air-launched with GPS-aided inertial navigation, has an imaging infrared seeker and fire-and-forget or MITL (with two-way AWW-13 communications pod) for target selectivity and moving target capability.
- TSSAM (AGM-137) Tri-Service Standoff Attack Missile – USAF/USN. Air-launched cruise missile with conventional warhead and 600nm range. Cancelled in EMD phase and essentially replaced by the JASSM program.
- JASSM (AGM-158), Joint Air to Surface Standoff Missile – USAF/USN. Air-launched, 250 nm nominal range, GPS-aided navigation and an imaging infrared seeker in terminal phase, an automatic target correlator, and a penetrating warhead. The JASSM has a one-way bomb impact assessment transmission via communications link.

Before and during these same years, other countries began to develop cruise missiles, many of which saw use in conflict and remain operational today. As would be expected, the Russians have developed a variety of cruise missiles. The sinking of the Israeli destroyer *Eilat* in 1967 by a Soviet-built Styx anti-ship cruise missile is often credited with renewing the USN's interest in cruise missiles. While there are many examples of foreign cruise missiles, most are relatively short range. France has developed a family of cruise missiles known by various names depending on their specific attributes (including the country that deploys it) such as APACHE, Scalp, and Storm Shadow. These French missiles are air-launched, land attack, standoff (i.e., relatively short range) weapons, with GPS-INS navigation and terrain following capability.

Sweden and Germany have together developed a land attack missile called Taurus, with terrain-matching navigation, an imaging IR seeker and a range of nearly 300 nm. Israel developed Delilah, again with GPS-INS, a datalink, a seeker, and a loiter capability with a nominal range of 150 nm.

Planned Cruise Missiles in Near Term

There is a continued desire to improve capabilities of cruise missiles by making them faster, better (range, accuracy, etc), cheaper, smaller, and easier to operate. Cruise missiles planned (that is in the program of record or being considered) for the near future include:

- Future Tactical Tomahawk – USN. Includes improvements in C2 and interoperability, more robust datalink, a multiple effects warhead, PTAN for GPS-independent navigation updates, ASUW, and mobile target capabilities. New launch platforms: include SSGN and DDG 1000. Possible Block V upgrade with high speed capabilities are also under consideration.
- JASSM-ER – USAF. Range of 500 nm with new engine, two-way datalink including capability for target update in flight. Includes planning for an anti-ship capability (2011 for JASSM-ER and 2012 for JASSM).
- JASSM–XR – USAF. Extra Extended Range version being considered with range up to 1000 nm. Launch platform would include bombers and heavy strike aircraft.
- Affordable Weapon – USN. As the name implies, a less expensive (<\$30K) capable “cruise-like” missile. Missile concept is rocket launched from a shipping container and powered in flight by a small turbojet engine with in-flight retargeting using a two way data-link. This missile would have a loitering capability and a payload of up to 200 pounds with a maximum range of up to about 800 nm.
- RATTLRS, Revolutionary Approach to Time Critical Long Range Strike – USN, USAF, NASA. This is a technology demonstration that is part of the National Aerospace Initiative and sponsored in part by Office of Naval Research (ONR). This concept has a turbine engine that operates at Mach 3.0 for about 5 minutes. It could be air-launched, as well as ship- and sub-launched.
- LOCAAS, Low Cost Autonomous Attack System – AFRL. This is a miniature air vehicle with a laser radar seeker, smart targeting algorithms, and a multi-purpose warhead. Intended to be employed against moving/relocatable targets and capable of multi-missile swarming tactics.
- SMACM, Surveilling Miniature Attack Cruise Missile – USAF. A proposal based on LOCAAS and Joint Common Missile technologies to be built from affordable, off-the-shelf components. Essential concept is a loitering, stand-off weapon that searches for targets with its on-board sensors.

During the past decade, there has been an increased emphasis on concept development, experimentation, and demonstrations aimed toward building a practical supersonic or hypersonic capability for aircraft and cruise missiles. Some relevant high-speed demonstration programs are described as follows:

- Fasthawk, Low Cost Missile System (LCMS) Advanced Rapid Response Missile Demonstrator (ARRMD) – ONR. This Advanced Technology Demonstration (ATD) was conducted in 1997 and 1998. Missile characteristics included a bending body, a rocket booster with ramjet engine that would have a 700 nm range and speeds of up to Mach 4.0. While LCMS terminated in 1998, this effort evolved into what became the HyFly concept.
- HyFly – DARPA/ONR. This is a hypersonic flight demonstration program using a dual combustion ramjet propulsion concept. Additional attributes of HyFly include high-temperature materials and hypersonic guidance and control. Concept variants would include surface ship, submarine, and air-launched missiles with ranges of about 600 nm, at speeds up to and greater than Mach 6.0.
- HyTech (Hypersonic Technology) – AFRL. This is a scramjet research and test program that is examining speeds of Mach 4.5 to Mach 6.5.
- JSSCM, Joint Supersonic Cruise Missile – DTRA/OSD/OPNAV. Came out of an April 2002 solicitation for a supersonic cruise missile ACTD that had a range of 400 nm and would operate at Mach 3.5 to Mach 4.5 with a CEP of 3 m.
- FALCON, Hypersonic Force Application and Launch from CONUS – DARPA/USAF. A reusable hypersonic cruise vehicle that can carry several munitions, including cruise missiles and bombs.
- X-43A (Hyper-X) – NASA. A cruise missile size, unmanned, air-breathing, hypersonic flight research aircraft, with speeds of Mach 7 to Mach 10. This aircraft reached sustained speeds of Mach 6.8 in March 2004 and Mach 9.6 in November 2004 at an altitude of near 100,000 feet.
- X-51 (Waverider) – AFRL. An air-launched hypersonic cruise missile for the B-52. Concept has launching aircraft at 35,000 ft. The missile's solid rocket booster accelerates to Mach 4.5, then scramjet to Mach 6 to Mach 7+. Tests are planned for 2007 – 2008 timeframe.

Discussion of Potential Cruise Missiles Capability Improvements

The following is a discussion of possible improvements that could be made to cruise missile characteristics.

Response Time – Response time can be reduced by moving the effective launch point closer to the target, e.g., launching from a manned (or perhaps unmanned) aircraft, using a loiter area from which to depart on cue, or using on-board ISR sensors to find and locate the target. However, moving closer to the target raises concerns of launch platform endurance, vulnerability and survivability.

Increasing speed of the cruise missile is another candidate area to reduce response time. It is difficult as of today to predict when and if a realistic super- or hypersonic capability for a U.S. cruise missile will be realized. It is often noted that other countries have developed supersonic cruise missiles, but these foreign weapons are mostly anti-ship missiles that are shorter range than what typically is expected for U.S. land attack cruise missiles. For example, a joint venture

between India and Russia produced the BrahMos anti-ship cruise missile with a range of 290 km (160 nm) and a speed of Mach 2.5+. This cruise missile became operational in 2006, and is believed to also have some land-attack capability.

The technological challenges of practical, long-range, land-attack cruise missiles in this speed regime go beyond propulsion area, which has understandably been the focus of high speed weapon experiments, demonstrations, and flight tests. Additional technical challenges for these high speed weapon concepts include thermal protection of the missile and payload, and communication techniques to allow the missile to receive in-flight navigation or targeting updates.

Terminal Guidance – Improvements in terminal guidance could include several areas: better capabilities to guide to the assigned aimpoint; on-board sensors to autonomously detect, identify, locate, and track the target; or increased flexibility for operators to designate the target and guide the missile to it.

Flexible Target Set Capability – Today, different payloads are required to effectively strike different targets. For example, much work is being done on a warhead that is effective against hard and deeply buried targets. An ideal capability might allow changing the effective payload configuration (and attack profile, if appropriate) just before launch or perhaps even during flight that is customized for the target.

Range – Currently, several long range cruise missiles can reach out to or beyond 1000 nm. Trade-offs of payload size and desired response times can be conducted to consider longer range “global strike” capable cruise missiles in the several thousand mile range.

Size – A smaller cruise missile could have advantages of more flexibility for the launch platforms (e.g., smaller UAVs) and stealth. The trade-off of a smaller cruise missile is potential reduced capability, specifically a shorter range and smaller payload.

DIRECTED ENERGY

Historical Review

It seems only natural that in any consideration of prompt global strike, that one should consider energy weapons that can kill or damage targets at the speed of light. The concept of such weapons, as represented by its technical enthusiasts and supporters usually includes the benefits of a deep magazine and low cost per kill since the “bullets” are only photons. But of course such bullets, if they are light waves, cannot penetrate clouds. Nevertheless, these energy weapon concepts have been around for a very long time and have always fascinated science fiction writers, warriors, and decision makers. H.G. Wells first described such weapons in his 1898 novel, *The War of the Worlds*, where he described an “invisible sword of fire that destroyed all it touched.” The first serious technical concept of a speed-of-light weapon appeared in the 1930’s, with the creation by Nikola Tesla (the inventor of AC power), of particle beams that could propagate through the atmosphere and defeat aircraft engines. This concept remained dormant for thirty years, but was resurrected again in the United States in the 1960’s as a method for shipboard defense against fast missiles. The Russians had their own version of “death beams” in the famous 1950’s novel, *Garin’s Death Ray*. The technically flawed concept captured the imagination of the Russian military, and there was a ready audience to support energy weapons after the laser was invented in 1961. This invention dramatically enhanced the idea since lasers were conceptually capable of delivering concentrated energy at great distances. One of the laser inventors, Nikolai Basov, who shared the Nobel Prize for this invention, became a powerful spokesman for beam weapons, and in 1963 he and others proposed that a nuclear explosion pumped laser could destroy an incoming reentry vehicle. With his enormous prestige, and the Soviet tendency to support their “great leaders,” a very large program, began in the Soviet Union in order to develop high power lasers for ballistic missile defense. The program employed many thousands of people, and involved the building of giant and very secret facilities. Although the program achieved heroic proportions, with the demonstration of a single laser pulse delivering over one million joules, the Soviets could not solve the problems of poor beam divergence and even worse technical management. In 1979 they moved on to another never explained technical challenge.

Although many people knew something big was going on, the U.S. was not specifically aware of Russian developments, and the U.S. had its own advocates for beam weapons throughout the 60s and 70s. Relatively minor funding was provided until Ronald Reagan, on March 23, 1983, asked scientists to provide a defense against ballistic missiles. That summer a DoD commission developed a plan that included \$5 billion for beam weapon research within an overall \$25 billion five-year program to determine the feasibility of ballistic missile defense. The Strategic Defense Initiative began in 1984, and substantial work began on space based chemical lasers and ground based excimer and free electron lasers. Other energy weapons work, such as the nuclear pumped x-ray laser, space based neutral particle beams, and high power microwave weapons also received funding, but the major support from industry advocates was for the space based chemical lasers. There was early hope that a solid state electrically pumped laser could be developed, but in lab experiments, most of the pumping energy went into heat instead of lasing, and the lasers could only be used for one shot and then had to be cooled for hours before being fired again. The chemical laser, on the other hand, offered high output power from the reacting

gasses, and used the flowing gases that reacted and were exhausted removing the waste heat. Even though this concept looked plausible for intercept of ballistic missiles in their boost phase, the proposal for an air based chemical laser, however, was thought to be unrealistic since it was believed that the plane would not be survivable over the Soviet Union.

Current Program

Support for the entire beam weapon program weakened after the fall of the Soviet Union, but efforts continued. Even though the aircraft based chemical laser was not considered for defeat of Soviet ballistic missiles, the concept received new support in the 1990s as a defense against theater missiles since the aircraft based chemical laser—with a range of only a few hundred kilometers—could fly outside the border of the threatening country. In addition, out of all of the beam weapon concepts, only the chemical laser had shown the potential for MW outputs, and by 2000 it was thought that an “initial capability could be fielded by 2010.” The DSB reported in 2001 that the concept of a directed energy weapon could “add a new dimension to a wide range of missions” because it can be “extremely fast and extremely precise.” The idea of a finely focused beam of light was again captured by the DSB, which said, “The laser beam delivers its energy to a relatively small spot on the target—typically a few inches in diameter. The incident intensity is sufficient to melt steel.”

In 2002, the Air Force Scientific Advisory Board (AFSAB) focused one of its summer studies on the concepts for “Immediate Attack Deep in Hostile Territory,” and stated that the job could be done by hypersonic missiles, but “not for at least 10 years,” and also suggested the aircraft based chemical laser—flying outside the borders of the enemy and using a relay mirror attached to an airship at an altitude up to 100,000 feet—could deliver energy to theater missiles above the clouds in the boost phase. The study pointed out that survival of the airship was of concern, but the concept “appears practical and harmonious with the Airborne Laser (ABL)’s missile defense role.”

The AFSAB also suggested attacking armored vehicles, “which might require about 10 KJ,” but also “causing enough confusion, delay, and disruption to disable normal launch operations. Personnel will not want to be near the area being irradiated.” The report neglected cloudy days, the possibility of the enemy hiding themselves and their equipment under a shelter, deploying dummy targets to soak up the laser fuel supply, or using their own lasers to blind the tracking optics of the laser weapon.

Today, the largest energy weapon program in the U.S. is the ABL weapon which is being developed to deliver standoff intercept of a theatre ballistic missile (TBM) in its boost phase. The chemical laser specifically developed for this application is planned for installation in a modified freighter 747 next year. Then the plan is to demonstrate destruction of a TBM one year after that. The laser has had many developmental challenges, and in addition, the beam control system has had many problems. For many years the critics of the program have argued that atmospheric perturbations of the laser beam, including the aero optics issues near the airplane, and countermeasures to harden the booster would limit the value of the weapon. The technical enthusiasts argue that there will be more advances in laser technology in order to stay ahead of a responsive adversary, and since the ABL is the only MW class laser weapon in development, the program should continue if for no other reason than to advance all of the underlying technologies. An issue that limits the applicability of the chemical laser is exhaustible energy

supply—particularly if the target is hardened. Another application of a chemical laser is to deploy it on the ground, using relay optics on an airship as a realistic air defense platform in clear weather.

Future Projections for High Power Lasers

One wonders with all of the technical enthusiasm, why is it that development of high power lasers has been so long in coming. This is because they have been large, heavy, unreliable, expensive, and generally too complicated to become practical mobile weapons. The applications that have justified expenditures in the \$1B per year range, such as the early SDI space based chemical lasers, were very futuristic to say the least. The ground based free electron laser (FEL) was thought to be more realistic using space based relay mirrors, but instability problems with the high energy electron beam that produced the laser beam prevented scaling of the FEL concept. In spite of the chemical laser issues, the U.S. investment has nevertheless been focused on chemical lasers because they have been the only approach that offers MW power levels, and much rides on the success of the ABL.

Even though chemical lasers have attracted much of the available DEW funding, important military applications of high power lasers may also be possible if electrically excited high power solid state lasers can be developed. Fiber lasers, that are efficient, light weight, easy to cool, and bright, can, in principle, be phased to achieve 100 kw levels with high beam quality with a relatively modest investment over the next five to ten years. In a March 2007 public document, DARPA claimed the following: “Tens of kilowatts output power and capability to scale to greater than hundreds of kilowatts output power and beyond will be demonstrated through coherent combining of the output power from multiple fiber lasers.”

This high level of optimism seems reasonable since the progress in high power fiber lasers has been rapid in the last few years, primarily because of U.S., foreign, and telecom investments. Their high efficiency and inherent large area to volume make them easy to cool so they may become leading candidates for weapon applications. A synopsis of the issues related to fiber lasers is provided in Figure D-5.

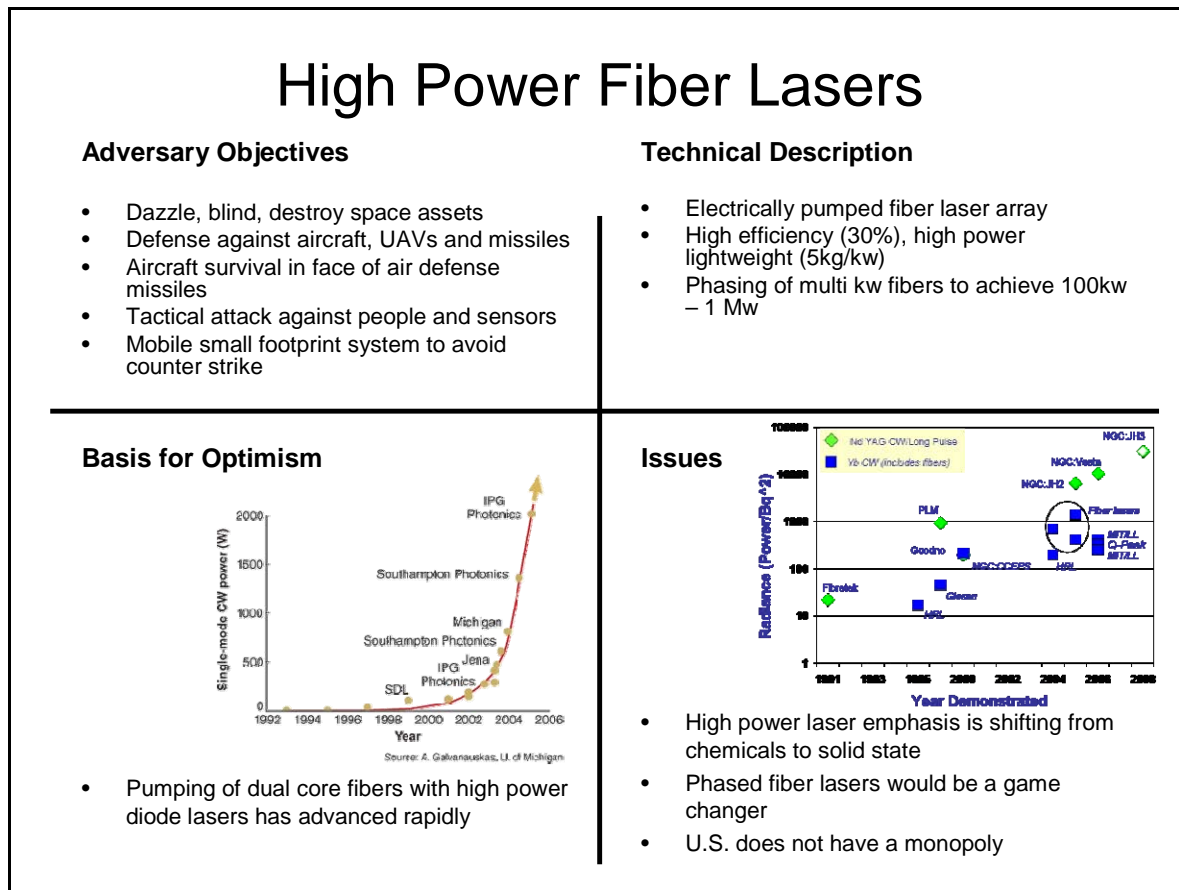


Figure D-6. High Power Fiber Lasers

One should note that these developments are well known in the laser community and these developments are not a U.S. monopoly. The other solid state laser approach uses slabs of glass that are face cooled or just allowing the glass to get hot and then recycled. They could also become practical in the 100 kw range, and the practicality of pumping, cooling, and aligning makes them “tricky,” but still much more promising than chemical lasers.

Electromagnetic Weapons

Even though lasers have attracted most of the technical attention and funding, a much smaller program has been pursued to use RF energy as a weapon to attack computers, networks, and communications. Even though RF energy propagation in the atmosphere is limited by air breakdown, the weather is not a serious limitation. The limitation, until recently has been the development of power sources of RF energy. One way to generate powerful pulsed EM fields over large areas is to use megaton nuclear weapons, lofted on large rockets and detonated at altitudes in the 100 km or higher range. The nuclear explosion will cause transient electric fields on the ground resulting from the weapon radiation interaction with the upper atmosphere. The electric fields can be calculated with small uncertainty, but the effects of the transient electric field depend on the details of the device attacked. A metal enclosure can shield out EM radiation, but a circuit or electronic device can be excited by the transient field if it can penetrate through the device enclosure. The effects could range all the way from temporary disruption to permanent damage of sensitive components. The level of the effects on the device or the system

depends on the details, and if we used such a weapon to disrupt our adversary, we would be faced with an uncertain outcome resulting from the serious escalation of detonating a nuclear weapon. In addition the detonation will cause the adversary to respond to this nuclear escalation in ways that could be very undesirable. Finally, the nuclear explosion would pump energetic electrons into the Van Allen belt, and radiation would destroy much of the electronics on low Earth orbit satellites over a period of a few months. With our higher dependence on space capabilities, this will lead to an unacceptable asymmetric disadvantage.

A non nuclear approach to EM weapons is called High Power Microwave (HPM) device that are portable high average power, or single pulse sources of EM radiation. They are powered by capacitors or high voltage generators coupled to vacuum tubes (such as the magnetron in your microwave oven) that radiate from a wave guide or an antenna. Recent advances in compact power generation, development of high power tubes, as well as growing vulnerabilities of electronic components and networks, make HPM of increasing military interest. If these weapons can be deployed relatively close to the target, and the target is an electronic device that is not perfectly shielded, energy can be coupled into the device or its circuit causing disruption or damage. The level of damage depends on the details of the coupling into the system and can range from a temporary interruption to permanent damage to sensitive components. Such devices have to be close to the target because of limitations in air breakdown and size of the radiation antenna. Nevertheless, the U.S. or its adversaries might choose to use such weapons as methods to functionally disrupt military capabilities in a covert and non lethal manner.

The concept of functional defeat of military networks and computers using methods that cannot be attributed to a specific attacker could prove to be useful. In the modern world which is so dependent on communications and computers, this much weaker form of energy attack than from laser beams, could ultimately prove to be the most realistic.

Even though charged particle beams were the first realistic proposal for beam weapons, they were found to be wildly unstable and were never pursued seriously. Neutral particles (negative ions accelerated and then neutralized) have been considered for space applications because of the extremely damaging characteristics of ions, but the power requirements and today's accelerator technology make this application unrealistic. If a nuclear multi megawatt space power source is ever developed, then solid state lasers may prove to be the weapon of choice for space wars.

In conclusion, the dream of powerful energy weapons that can deliver focused energy to distant military targets has had a long and arduous path that may now be coming to fruition in the not too distant future. The original idea of H.G. Wells of concentrated heat rays that can melt steel, has become a commercial reality for industrial applications, and with the recent development of powerful solid state lasers, could lead to practical mobile military applications in the next ten years. Even though kilowatt levels have been reached with efficient, light weight, high beam quality fiber lasers, phasing multiples of such fibers has yet to be accomplished, but in a short time such a demonstration at the one hundred kilowatt level could lead to a revolutionary military capability. Such lasers on mobile platforms could be used for dazzling and blinding of sensors, and with scaling to multi megawatt power levels in ten to twenty years, could provide lethal levels of power at distances on the order of hundreds of km. Of course such lasers can not operate through clouds and can be seriously degraded by weather conditions. The charged particle beam concept actually preceded the invention of the laser, and offered the potential for

all weather operation and higher lethality than lasers, but it was rejected because the basic beam stability physics problems that could not be solved. Powerful neutral particle beams are possible as space weapons, given a light weight multi megawatt space nuclear power supply and substantial advances in particle accelerators. The other all weather energy weapon is the use of electromagnetic energy from high altitude nuclear explosions to attack large terrestrial areas with pulsed electric fields of several kV/m, or the close in application of bursts of high power microwaves to relatively soft targets such as unshielded electronic components or circuits. Nuclear weapons are certainly an existing and proven approach to global strike, and although they can provide terrestrial effects if detonated in space, their effectiveness remains uncertain depending on the detailed hardening of the targets, and are difficult to quantify for certain kill applications. The limited range of high power electrically generated microwaves makes them unrealistic for attacking distant targets, but could become real for non attributable attack on soft targets. Thus the only practical and relatively near term concept for prompt global strike using energy weapons would be air based efficient, bright, light weight, powerful electrically pumped solid state lasers. The electric power from the aircraft could provide the "deep magazine" and would allow the aircraft to operate for extended periods even in the face of a determined air defense. The eventual emergence of air based laser battle stations dueling each other above the clouds at the speed of light seems to be a realistic possibility, and if deployed in space, could eventually lead to the reality of "Star Wars."

SPECIAL OPERATIONS

Background

The Special Operations Force is a Joint Force consisting of Army, Navy, Air Force and Marine Special Operations personnel and units. The entire force is approximately 45,000 personnel. The United States Special Operations Command, located at MacDill AFB in Tampa Florida is the Combatant Commander of the multi service component commands. The Force may deploy in unit sizes ranging from a small detachment of two to six people to a joint Special Operation Task Force that will be comprised of ground units such as the Army Special Operations Forces (Green Berets, Rangers, TF 160), maritime units such the Naval Special Warfare Forces (SEALs, select submarines and Combatant Craft Crewmen) and air units such as the Air Force Special Operations Force (fixed wing, rotary wing, and combat control team personnel). Each Theater commander has a Special Operations Command (SOCEUR, SOCPAC, SOCCENT, SOC Korea, SOCSOUTH, SOCJFCOM) to whom deploying SOF forces report. These SOC's command the JSOTFs (Joint Special Operations Task Force) that execute operations ranging from Mobile Training Teams and Foreign Internal Defense Missions to Strategic Reconnaissance and Direct Action (Strike) missions. The USMC Special Operations Command is the newest branch of SOF and has been initially focused on conducting Foreign Internal Defense. Perhaps the biggest change in the configuration of the USSOCOM has resulted from its assignment for responsibility to plan, direct and execute the Global War on Terror against Al Qaida. This assignment has resulted in USSOCOM conducting global counter terrorist missions that cross the "boundary lines" of the various theater commanders.

SOF: A Powerful Option for Time Critical Strike

It is clear from the briefings presented to the DSB panel and from its analysis of various time critical scenarios that the SOF option is a powerful one. The SOF option contains the ability to sense the target, decide the course of action, execute it on the fly, assess the results of the mission then and there, and relay any key intelligence gathered during the mission that may allow immediate follow on time critical strike elsewhere against that enemy.

Pros and Cons

There are six key aspects to utilizing the Special Operations Force for a time critical strike that the Task Force would categorize as **Pros** for that option:

1. **Positive Identification of the Target:** SOF operators on the ground can positively identify the target.
2. **Minimize Collateral Damage:** A SOF strike will likely minimize collateral damage.
3. **BDA and Effects Assessment:** Having SOF on the scene will allow for real time battle damage and effects assessment to include the identification of victims, the capturing of targeted individuals, and the collection of valuable intelligence material for future strike.
4. **Collection and Distribution of Intelligence for Follow On Strike:** The SOF Team can quickly relay captured information about other targets (particularly involving

terrorist teams, individuals, locations and plans) that can be quickly attacked or neutralized before word can be spread amongst the enemy about the original strike and/or capture.

5. **Clandestine Nature of the Operation:** In many instances a SOF time-critical strike can be done in a clandestine manner that leaves no trace of any action or leaving the enemy to wonder what really happened and who did it. Both are powerful psychological aspects of a time critical strike.
6. **Psychological Impact:** A SOF mission could be conducted in such a manner that the results of the mission are realized by the “enemy,” but the method of mission success can not be detected. This leaves the “enemy” with the impression that the United States can conduct operations against them at any time or in any place. This can be particularly effective if used in combination with a targeted information campaign.

Similarly there are four key aspects of utilizing SOF that the Task Force would consider to be the principal **Cons** in a time critical strike scenario:

1. **Distance from the Target and Transit Time:** Even the most forward deployed SOF unit and even the units that are on the highest alert may often be too far either in distance or time to reach the target and bring about the desired effect in time.
2. **Detectability:** Even using aircraft, vessels or vehicles with as many physical and electronic stealth features as we can incorporate on those platforms, the transit of the SOF team may very well be detected and cause the enemy to be alerted in sufficient time to disperse and thus make a time critical strike not feasible.
3. **Vulnerability:** SOF forces are inherently light, agile forces. As a result they are not heavily armed and are vulnerable to attack if detected. If the protection around the target is deemed to have a high concentration of enemy forces and especially if those forces are equipped with effective sensor (RADAR, SONAR, ELINT, etc..) and communication systems, it may result in a the assessment that the probability of mission success on a time critical strike is therefore low and/or the casualties that the force might suffer are not worth the risk.
4. **Cross Border Operations:** Since a Special Operations strike mission would often involve cross border operations, the political and legal aspects that one would associate with an intrusion into another country’s airspace, maritime limits, or across its border come into play. The ramifications of those aspects of the operation may make it politically unacceptable.

Overall Assessment – The study’s overall assessment is that the Special Operations Option is particularly attractive and can have a high probability of mission success in the permissive and semi-permissive mission environments. To expand into the non-permissive environment would require a significant improvement in speed of delivery and stealth, as well as rapid methods to recover or reinforce the force.

The System we have now WORKS. We need to sustain it. The Task Force learned from its briefings that the system that the United States Government now has within its various agencies and with the U.S. Special Operations Forces is already effective in prosecuting certain types of

time critical strikes using special operations forces. The Task Force's strong recommendations are:

- Continue to support that system, the forces, the key C4I elements and the SOF delivery platforms that are described below.
- Regularly exercise the system to include the actual principle decision makers within the White House, the National Security Agency, and the various Departments. This is key when there is a change of presidential administrations or key cabinet members.

Rapid Target ID, Planning and Execution are Key. The Task Force was impressed that the system allows for rapid dissemination of a time critical intelligence that enables the Special Operations Forces to quickly develop a plan and execution check list with pre-planned ROE and risk analysis. We recognized that there were formatted check lists and decisionable briefing packages that top DoD officials were familiar with and today enable them to rapidly assess the situation, the proposed plan and then issue mission execution orders.

Proximity to the Target and Speed of Response is the Key. Obviously the long pole in the tent for SOF is executing a time critical strike is getting to the target quickly. The Task Force saw five key elements that enabled SOF in this mission:

- Having SOF forces that were already geographical and cultural "experts" of the most likely hot spots.
- Forward Basing in the expected area of operations.
- Complex information/intelligence sharing systems.
- Automated planning systems that fed directly into pre-formatted decisionable briefing tools that allowed rapid decision making at the highest levels of command.
- Rapid response airlift both from CONUS and within the area of operations.

The Task Force was impressed that while those decisions were being briefed and made, the SOF force was already on the move toward the target with the necessary mission package, but still in full communication with the authorizing authorities. The SOF force was thus poised to execute by the time the order was received, yet had not violated any cross border or ROE concerns until the order was given. This was clearly not only part of their training, but routinely executed in real world missions over the past few years.

Forward Deployed at Any Hint of Trouble. The Task Force notes that the key to SOF appropriate time critical missions was to have the SOF force forward deployed near the potential targets. They are in Iraq and Afghanistan and in the surrounding countries where the U.S. has forces based and the time critical missions that they conduct there are only possible because of their proximity to the targets. The Special Operations Command policy of deploying forces to countries that count would seem key if the U.S. is to continue to have this option at hand.

Speed: Similarly, the platforms that deliver SOF, particularly the helicopters and CV 22 that are so key in delivering them right on top of the target, must be continued to be supported and

enhanced. Any capability that enhances rapid decision making, information sharing and the speed of movement of the force should be considered.

Risk: The SOF Option is not without Risk. The Task Force fully recognizes that using SOF, or any other force puts people at risk, opens up the possibilities of U.S. fatalities, foreign fatalities of innocents, casualties, captives/MIAs, and the political situations that arise from those outcomes. We are also aware that there are key political considerations and international laws that become involved, especially when the SOF mission involves cross border actions. In Task Force discussions and briefings it was clear that the department and the Special Operations Command fully understand these considerations which are an integral part of the planning process. We believe that the legal/political decision system that is used for these missions could be applied to making execution decisions for kinetic time critical strikes.

Importance of SOF to SOF relationships. In several of the scenarios that were examined, particularly the killing or capture of terrorist leaders at a remote meeting site, the securing of fissionable material, or the interception of WMD material as it transited through neutral or friendly countries, it was quickly recognized that the likely route the U.S. would take would be to work closely with the host nation involved, support their forces with our own Special Operations force, and “allow” them to make the capture or secure the material. This led the Task Force to recognize the importance of the global foreign internal defense mission that the Special Operations Command prosecutes wherein SOF forces go to various countries and train extensively with their SOF counterparts. Thus, when a time critical strike mission arises, the necessary personal relationships among the executing forces that lead to mission success already exist. We would recommend that the Department continue to support those FID/MTT programs and obviously focus them on those countries where we might expect trouble in the decades to come.

INTELLIGENCE/SURVEILLANCE/RECONNAISSANCE (ISR)

A common requirement for all time-critical, standoff strike scenarios and all conventional weapon alternatives is precise and accurate knowledge of the target characteristics and its location. Because of the strategic implications of attacking these targets, it is essential to know that the proper target has been selected and to be able to confirm reliably that the target has been destroyed consistent with the strike objectives. The U.S. ISR infrastructure is responsible for collecting, analyzing and reporting the information required to address these needs. For all the scenarios evaluated in this study, the availability of prompt, timely and accurate ISR information to support target identification and geolocation is at least as challenging as the weapon flight time and delivery accuracy. It is unlikely that any single ISR system will be adequate, and it will be necessary to integrate data collected from multiple sensor systems to identify and characterize the target sufficiently.

The first part of this section describes the overall ISR requirements for time critical strike, followed by a description of the unique ISR issues associated with specific classes of targets and a discussion of the types of ISR systems currently deployed. The section concludes with voids and gaps of current ISR capabilities.

ISR Requirements

The primary ISR requirements to support time-critical strike from standoff were derived by the Task Force through analysis of the scenarios that formed the foundation of the study. The requirements include:

- Information to understand the enemy culture and values to assist in discerning and interpreting the intent behind their actions.
- Precise and accurate target geo-positioning.
- Detailed characterization of the target and its surrounding area to ensure proper identification and to provide the ability to forecast collateral damage associated with the attack.
- Coverage that is persistent enough (or with a sufficient revisit rate) to support detection of time critical events along with low reporting and analysis latency to support timely decision making and strike execution.
- Reliable BDA capability to allow post-strike confirmation that the desired results have been achieved.

The following paragraphs briefly expand upon each of these requirements.

Intelligence plays a key role in identifying enemy goals and the activities or assets the enemy considers key to meeting those goals. Without such knowledge, ISR may not discern enemy centers of gravity, much less yield actionable information with sufficient surety for targeting purposes.

Avoidance or minimization of collateral damage dictates precision strike with non-lethal weapons or weapons with strictly local effects. From an ISR perspective, this means ge positioning of target aimpoints to accuracies of a few meters.

In many cases, ISR must characterize not just the strike objective itself, but its environment as well. Such characterization may be critical to penetrating defenses, to selecting an appropriate weapon, and to ensuring weapon effectiveness, as well as to controlling collateral damage.

Persistent ISR may be required to detect and/or identify some classes of targets based on changes in the target itself (e.g., construction, transformation or movement) or of tell-tale activities (e.g., communications activity, building exhausts, fuel truck movements, etc.). For relocatable or transient targets, ISR latencies must also be small enough to support timely command and control and strike.

Willingness to execute a particular strike option will be enhanced if leadership can be confident that ISR will provide an accurate assessment of damage. In some cases, rapid BDA may be required to support post-attack decisions regarding re-attack, defensive action, diplomatic notifications, or consequence management.

Unique Target Issues

The scenario analysis identified several different classes of targets that may be suitable for prosecution by a time-critical standoff strike weapon including:

- Fixed targets that are known with sufficient advanced warning to support detailed target preparation.
- Hard, deeply buried targets whose location may be known but whose detailed structure is deep underground and may not be observable.
- Moveable targets that must be located and struck before they are relocated.
- Transient targets such as known meeting locations that are only important when persons of high value are present.
- Ad hoc targets where a strike needs to be prosecuted immediately after the target is first detected if there is to be any reasonable chance of the strike being effective.

The following paragraphs elaborate on the characteristics and unique ISR challenges of each target class.

Fixed, above ground targets such as power plants, high power laser facilities or weapon laboratories or factories are most amenable to precise, high confidence strike preparation. Multiple ISR assets may be cross-checked over an extended period to unambiguously determine the nature of the target, and to identify the critical portion for weaponeering and attack optimization. If appropriate, ISR can also be tasked to assess nearby activities and facilities in order to refine strike plans to avoid defenses and to minimize collateral damage. Relative to other target classes, fixed above ground targets are also most conducive to unambiguous BDA via remote ISR.

Hard and deeply buried targets (HDBT) are also amenable to ISR collection and analysis over an extended period. On the other hand, remotely locating and characterizing key assets or activities within an HDBT may not be possible, even when the initial construction of the facility has been observed. In the absence of detailed target characterization, selection, targeting, attack planning and damage assessment for precision weapons may be impossible, potentially dictating employment of large numbers of penetrators to assure wholesale destruction. ISR may also have great difficulty identifying all necessary aimpoints to support alternative tactics designed to temporarily neutralize or trap high value assets within an HDBT by striking adits, air vents, communications facilities or power sources.

Much greater ISR challenges are presented by movable targets, such as a rail car or a deployed missile transporter-erector-launcher (TEL). Not only must such targets be identified, geotyped and characterized with high assurance, but successful strike may depend entirely upon the speed of the ISR TPED (tasking, processing, exploitation and dissemination) process. Unless strike systems are employed that can prosecute moving targets, ISR may need to disseminate up-to-date target coordinates directly to the strike system in flight, within the static dwell time of the target. That dwell time might vary from an hour to fuel and arm a liquid ICBM to a few minutes to erect and arm a solid rocket or unload a shipping container or special nuclear materials (SNM) from a rail car. When available, close-in ISR assets might meet tight requirements for timely identification and characterization, while also providing designation for terminal homing weapon guidance systems and supplying real time BDA.

Similar ISR challenges arise in the case of any transient target, even if the specific location of the strike can be preplanned. A canonical example is a terrorist leadership meeting at a known location. Given ISR that identifies the meeting place, geolocation and characterization of the meeting room, building and neighborhood can be developed over a period of time to support weaponeering and strike planning. Close-in and persistent surveillance of the terrorist leaders themselves may be required, however, to overcome leadership OPSEC (e.g., COMSEC, disguise, decoys, etc.) and determine that the terrorists are indeed enroute or at the pre-planned strike location. Close-in ISR may also be required if high confidence, near-real time attack assessment is desired.

The most vexing ISR challenges may be ad hoc targets, where a strike must be executed against a previously uncharacterized transient target in an unanticipated location, immediately after the target is detected. One example might be WMD being transported in a terrorist back pack. This class of target may not be detectable or identifiable unless close-in ISR is on the scene. Given close-in ISR, rapid TPED must be tightly integrated with a quick response strike system if significant force is required to contain the prospective threat.

Current Types of ISR Systems

ISR systems are generally characterized by the platform and sensor type that provide the collection capability. This section discusses ISR systems by platform type – satellite, airborne, close-in collectors, human intelligence (HUMINT) and cyber collectors. For the time critical mission, the ability to promptly deploy the ISR platform against the suspected target may be an essential ingredient for success.

Space-based sensors – Space basing ISR sensors provides the broad geographic coverage areas and the long standoff ranges mean that the systems have, to date, been relatively secure from attack or interference. However, the recent Chinese direct-ascent anti-satellite demonstration indicates that, in the future, there should be more concern about the survivability of satellite-based ISR systems.

Imaging sensor options include both passive (optical, infrared and multi/hyper spectral) and active (radar) systems. The resolution of passive sensors is strongly influenced by the satellite altitude so these systems are almost always deployed in low earth orbit (LEO).

One of the critical products that are uniquely derived from satellite-based optical imagery is wide-area mapping. These maps, are often the source of the precision geo-referenced coordinates used for weapon targeting.

The imagery products are also used to detect changes over time that support monitoring adversaries and result in identifying and selecting targets. This analysis is currently manually intensive and requires extensive human judgment. However, there has been extensive technical research in image processing and related detection algorithms to assist in this task. Progress has been mixed, with the goal of completely automatic target recognition still being illusive. The best success has been in situations where there is a good description of the target that can be represented in a template for automated use. Even in these circumstances, human-assisted techniques have been more effective than fully automated ones.

Signals intelligence (SIGINT) sensors collect radio frequency emissions associated with both military (radars, air defense systems, communications, etc) and civilian (communications, air traffic control, etc.) infrastructure. The processing systems both localize the source of the emission and analyze the content to identify the target (e.g., by using signal waveform structure) or to develop broader intelligence information (as can be gleaned from translating intercepted communications). Much of the initial SIGINT data processing is automated; however, the detailed intelligence exploitation of communication intercepts still requires significant manpower.

Measurement and Signatures Intelligence (MASINT) sensors are directed at collecting other than image or signal information that can be used to characterize, classify and identify targets. This information may include the chemical composition of emissions, thermal signatures or material makeup of the target of interest.

The final type of sensor is one that provides Indications and Warnings (I&W) of pending activity by an adversary. The classic I&W platform is the Defense Support Program (DSP) which has deployed an array of satellite-borne infrared sensors that detect the heat from missile plumes and provide early warning of missile launches. However, the data collected by both imagery and SIGINT can be processed for I&W purposes.

Each of the different sensors has a similar cycle – referred to as TPED – for controlling and analyzing the information they collect. These activities are currently “stove piped” in that each sensor-platform generally has its own dedicated infrastructure. All current systems collect massive quantities of data and, as discussed, require significant manual processing. As a result,

timelines from collection to actionable intelligence can be long. One of the key concerns identified by the Task Force, based on evaluating our representative scenarios, is the ability of the ISR systems to provide the accurate and timely targeting information required by the time-critical, standoff strike weapons.

There are several proposals under consideration for improving the effectiveness and timeliness of ISR systems. The most promising are movement to a task, post, process and use (TPPU) control and exploitation cycle and integration of information from diverse sensors. Adoption of a TPPU cycle exploits the benefits of the netted, collaborative Global Information Grid (GIG) to break the possessive control of ISR data by its owning organization. Near-real time tagging and posting of raw sensor data before they are processed allows more organizations to access and rapidly use the information before the processing cycle is complete. Processed products are also posted as soon as they are available. Integration of data from different types of sensors should significantly improve target identification and characterization. The broad access to tagged and timed raw sensor data enabled by the TPPU/GIG infrastructure is critical to this integration capability.

Airborne sensors – All the different sensor types discussed above in the space-based environment are also deployed on manned and unmanned airborne platforms. The properties of the various sensors are the same as discussed above. The key difference for airborne basing is that the sensors are closer to the target area, which generally improves the resolution of passive imagers. The closer proximity to the target may increase the vulnerability of the collection platform to enemy defenses. However, the increased use of unmanned air vehicles, such as Predator, may make the risk acceptable. Also, high altitude airborne platforms, such as Global Hawk, U-2 or SR-71 generally operate outside the range of air defense systems for all but the most sophisticated adversaries, so their vulnerability is likely to be similar to space-based sensors.

An additional challenge unique to airborne ISR platforms is the time required to deploy the platform to the target area. This requirement may delay the timeliness of ISR collection for ad hoc mission scenarios. One of the ways to address this problem is to develop and deploy long endurance platforms that provide persistence of sensor coverage over the target.

Airborne platforms also have difficulties providing high-precision metric accuracy necessary to generate the very low target location error required by time-critical, standoff strike weapons. Currently, the only source for precision mapping data is satellite-based imaging systems. However, there are on-going initiatives within both the Air Force and NGA to address the metric accuracy challenge for the Predator platform. The USAF Target Location Accuracy (TLA)⁴ initiative is focused on improving on-board navigation, timing and metadata synchronization to deliver limited geopositioning capability.

Because airborne ISR systems have limited ranges and require extensive support structures, there will frequently be significant U.S. forces in the regions where they are operating. In these situations, the U.S. may have other viable time critical strike options and the standoff weapon alternatives studied by the Task Force may not be needed.

⁴ NGA Information Paper U-016-07/IJC, May 30, 2007.

Airborne ISR systems have all the TPED volume and timeliness issues that were discussed for space-based systems. Each of the currently deployed airborne systems also has a dedicated, “stove-piped” ground system. All of the enhancements associated with a TPPU control cycle and integration of sensor-collected data across modalities apply equally well to airborne ISR.

Close-in collection – Many of the targets for time-critical standoff strike, including WMD sites, identifying and locating terrorist leaders, and characterizing HDBTs, pose very difficult ISR challenges for standoff sensors because the relevant signatures are not detectable from long distances.

The sensor types used in close-in applications include acoustic, seismic and chemical detectors among others. The key technical challenges for close-in collection are concealment from detection, delivery to close proximity to the target, and exfiltration of the data from the sensors. Small size for sensors, batteries and antennas, power-efficient electronics designs, and low-probability of intercept waveforms are essential to achieving the required capabilities.

One important class of close-in ISR sensors are Tagging, Tracking and Locating (TTL) devices. In some cases, the target is physically tagged with a device that can track and report the location of the vehicle or person as it moves. TTL requires very small size and low power to support concealment and very clever signal exfiltration techniques to support position reporting or tracking. However, these devices can be used very synergistically with other ISR sensors to provide the benefits of effectively continuous coverage with lower levels of persistent for standoff sensor platforms.

Most close-in collection tends to be in ad hoc/special operation type missions. This is a result of the fact that there is no “natural” acquisition or operational sponsor for close-in collection systems. Consequently, the “sensor to shooter” link may be constructed uniquely for each situation and it may be difficult to close this loop in a timely enough manner to support time-critical strike. However, when close-in sensors can be placed in a manner where the sensor to shooter loop is closed, they may be very effective in providing essential data for increasing the accuracy and reliability of target identification, an essential requirement of many of the strategic strike scenarios.

HUMINT – Some of the information decision makers will need for timely and confidently employing time-critical standoff strike weapons cannot be developed by physical sensors. There is broad recognition that the trans-national terrorist and WMD threats require the U.S. to significantly reinvigorate its human intelligence collection capability. This requires a long-term investment and will not likely yield immediate results. However, it is essential to understanding the adversary’s intent, knowledge of which should ultimately reduce decision making timelines when the strategic use of time-critical standoff strike is being considered.

Cyber ISR – The global reach of, and reliance on, the internet and netted computing and communications provides another potentially valuable ISR platform. The extensive reliance of the U.S. on net-centric warfare increases our vulnerability to computer security threats. The flip-side of computer network defense is computer network attack. These techniques can be used both offensively to disrupt adversary operations and for covert penetration as a means to intelligence collection.

Most of this cyber-collection will likely support long-term background intelligence. However, if appropriate penetrations can be effected, it may be possible to do real-time surveillance to support time-critical decision making. One of the key challenges of using cyber-ISR data for targeting will be the difficulty of reliably geo-locating the source to support a physical attack. Of course, it may be possible in some cases to achieve the desired effect on the enemy with a cyber attack.

Key Capability, Voids and Shortfalls

Many of the scenarios that the Task Force evaluated severely stressed the ISR resources, both in having the information to support a timely, confident decision to strike and in being able to determine reliably after the attack that the target had indeed been destroyed. There was significant discussion of the decision timeliness and whether the national command authority was capable of responding quickly enough to take advantage of the target vulnerability window. Improved ISR is an important element of reducing the time to make these critical decisions.

The primary weaknesses of the existing ISR infrastructure relative to these decision-making needs were identified as:

- Understanding enemy culture and values to discern intent.
- Precision target location accuracy for sensors, particularly those on airborne platforms, that do not have metric sensing capability.
- Timely and accurate characterization of target area to estimate collateral damage.
- Ability to identify and track key individuals.
- Close-in ISR systems tailored to WMD detection.
- Aimpoint selection for defeat of HDBTs based on knowledge of interior target characteristics.
- Reliable BDA from strategic standoff.

Detailed treatment of these ISR shortfalls is beyond the scope of this study, the terms of reference focused on evaluating time-critical standoff strike alternatives. However, ISR support is so critical to overall mission success in all scenarios that the Task Force considered it critical that its report highlight these issues.

INFORMATION OPERATIONS (IO)

The DOD has established the following definitions for the use of information, cyber space and electronic capabilities to gain a military advantage over the adversary:

“Information Operations (IO) are the integrated employment of the core capabilities of electronic warfare, computer network operations, psychological operations, military deception, and operations security, in concert with specified supporting and related capabilities, to influence, disrupt, corrupt or usurp adversarial human and automated decision making while protecting our own.”⁵

Electronic warfare (EW) is any military action involving the use of electromagnetic and directed energy to control the electromagnetic spectrum or to attack the enemy. The three major subdivisions within electronic warfare are: electronic attack (EA), electronic protection (EP), and electronic warfare support (ES).

Electronic attack is that division of electronic warfare involving the use of electromagnetic energy, directed energy, or anti-radiation weapons to attack personnel, facilities, or equipment with the intent of degrading, neutralizing, or destroying enemy combat capability and is considered a form of fires. EA includes: 1) actions taken to prevent or reduce an enemy’s effective use of the electromagnetic spectrum, such as jamming and electromagnetic deception, and 2) employment of weapons that use either electromagnetic or directed energy as their primary destructive mechanism (lasers, radio frequency weapons, particle beams).

Electronic protection (EP) is that division of electronic warfare involving passive and active means taken to protect personnel, facilities, and equipment from any effects of friendly or enemy employment of electronic warfare that degrade, neutralize, or destroy friendly combat capability.

Electronic warfare support (ES) is the division of electronic warfare involving actions tasked by, or under direct control of, an operational commander to search for, intercept, identify, and locate or localize sources of intentional and unintentional radiated electromagnetic energy for the purpose of immediate threat recognition, targeting, planning and conduct of future operations. Thus, electronic warfare support provides information required for decisions involving electronic warfare operations and other tactical actions such as threat avoidance, targeting, and homing. Electronic warfare support data can be used to produce signals intelligence, provide targeting for electronic or destructive attack, and produce measurement.

Computer network operations (CNO) are comprised of computer network attack, computer network defense, and related computer network exploitation enabling operations.

Computer network attack (CNA) are actions taken through the use of computer networks to disrupt, deny, degrade, or destroy information resident in computers and computer networks, or the computers and networks themselves.

⁵ Joint Publication 3-13 Information Operations, dated February 13, 2006.

Computer network defense (CND) are actions taken through the use of computer networks to protect, monitor, analyze, detect and respond to unauthorized activity within Department of Defense information systems and computer networks.

Computer network exploitations are enabling operations and intelligence collection capabilities conducted through the use of computer networks to gather data from target or adversary automated information systems.

Military deception (MILDEC) are actions executed to deliberately mislead adversary military decision makers as to friendly military capabilities, intentions, and operations, thereby causing the adversary to take specific actions (or inactions) that will contribute to the accomplishment of the friendly forces mission.

Operations security (OPSEC) is the process of identifying critical information and subsequently analyzing friendly actions attendant to military operations and other activities to: (a.) identify those actions that can be observed by adversary intelligence systems; (b.) determine indicators that hostile intelligence systems might obtain that could be interpreted or pieced together to derive critical information in time to be useful to adversaries; and (c.) select and execute measures that eliminate or reduce to an acceptable level the vulnerabilities of friendly actions to adversary exploitation.

Psychological operations (PSYOP) are the planned operations to convey selected information and indicators to foreign audiences to influence their emotions, motives, objective reasoning, and ultimately the behavior of foreign governments, organizations, groups, and individuals. The purpose of psychological operations is to induce or reinforce foreign attitudes and behavior favorable to the originator's objectives.

Military operations are conducted to gain certain political objectives. Often military operations are not complete victories. Political decisions are typically won by convincing the adversary not to fight (desired option) or to convince them to quit fighting. IO are essential to effectively support military kinetic operations and have the capability to shape the mind and the resolve of the adversary. Strategic Communications (a part of PSYOP) which are targeted at shaping the adversaries mind through communication in various media forms are separate from IO which creates undesirable effects in the information networks of the adversary or exploits those networks.

Modern economies are integrated with Information Technology (IT) and in most cases failure of a nation's IT infrastructure will result in economic collapse. The U.S. military capability is critically tied to IT with the Net-Centric Strategy, GPS technology and integration (albeit protected), with the internet. In general IT is highly vulnerable to attack, intrusion and manipulation and the U.S. military system is no exception even though it has many extra protections. Total information assurance is impossible. Any adversary capable of an effective attack on the U.S. military system can also attack the civilian and private sector infrastructure and bring significant and potentially sustained consequences to the nation's economy.

The principal objective of an IO strategy is to convince the adversary to agree to an acceptable settlement, and there are many tactics and methods to achieve that goal. Information warfare

effects can add confusion to the battle, destroy confidence, and destroy infrastructure capabilities that support the population and the war/battle. In addition these effects can often be deployed remotely without attribution. However, BDA is difficult to predict and assess.

For the U.S. major IO national security issues exist. Detection of an IO attack is difficult, attribution is difficult, commercial IT is readily available worldwide and much is produced by foreign sources. An IO attack is unique in that the consequences of effects generated are available to all adversaries almost independent of resources while current defense strategies against such attacks are not adequate.

In a sense IO is the ultimate time-critical stand off weapon in that it can be delivered with the speed of light and is often without attribution. Yet it is almost as available to U.S. adversaries as it is to the U.S. and the U.S.'s own IO strategies are in their infancy.

C3 ISSUES

The command and control of time-critical conventional long range strategic strike forces will require attributes similar to those of U.S. strategic nuclear forces. The U.S. Nuclear Command Control System (NCCS) performs the following essential functions, all of which are germane to long-range strategic strike:

- Planning
- Situation Monitoring
- Decision Making
- Force Direction
- Force Management

To perform these essential functions and in light of the profound implications of their use, the following are required attributes of nuclear command and control (extracted from DoD S5210.81, US Nuclear Weapons C2, Safety, and Security – the DoD Implementer for NSPD 28). Many of these applications are applicable to global conventional strike forces:

- Nuclear weapons shall be subject to the most precise and stringent C2, safety, and security possible.
- Personnel assigned to NCCS positions shall possess the utmost reliability and shall be subject to a personnel reliability assurance program. Personnel shall be fully qualified and have their reliability verified prior to assignment to the position.
- Designated NC2 personnel include, but are not necessarily limited to, those personnel with access to the NCCS coding and authentication process and a communications medium necessary to transmit release, execution, or termination orders; those personnel involved in the preparation and production of NCCS coding and authentication and equipment; those personnel involved in preparation and production of nuclear weapons targeting tapes and material; and those maintenance and security personnel who could have an adverse effect on systems performance for nodes and equipment that represent near-single-point failure elements of the NCCS.
- Information Assurance: Measures that protect and defend information and information systems by ensuring their availability, integrity, authentication, confidentiality, and non-repudiation. This assurance includes providing restoration of information systems by incorporating protection, detection, and reaction capabilities.
- Positive surety measures: The combination of procedural and administrative actions, physical safeguards, and design features to ensure the security, safety, and control of nuclear weapons and systems, including associated personnel. The capability to ensure a state of protection against hostile or unauthorized acts, influence, or disclosure.
- Reliable: The capability of performing its intended function at required levels, for a specified interval, under stated conditions.
- Responsive: The capability to react within specified period, under stated conditions, to accomplish a designated objective.

- **Robust:** The qualitative measure of a system, capability, or process to withstand across a range of plausible events or stressed environments, or recover gracefully to specified levels within prescribed time limits. This measure is primarily influenced by two factors – ruggedness and redundancy.
- **Survivable:** The capability to avoid or withstand hostile and/or stressed environments, including physical, EMP and information attacks. For NCCS elements identified as critical, this capability shall be obtained through a combination of systems that can both “operate through” and/or “recover from” the most hostile threat environments to ensure the uninterrupted control of nuclear weapons.
- **Enduring:** The capability to sustain operations at specified levels of performance before, during, and after hostile events or operating within stressed environments.
- **Flexible:** The capability of meeting changing situations with timely, effective, appropriate, and adaptable reactions to the full range of plausible scenarios.
- Measures developed shall assure the authorized use of nuclear weapons when directed by the President while assuring against their unauthorized or accidental use (assure versus assure against balance).

In general, the command and control of nuclear forces is administered through the National Military Command System (NMCS), an integrated network of facilities, equipment, doctrine, procedures, personnel, and communication systems. The NMCS supports and implements Presidential authority through a military chain of command to enable planning, situation monitoring, conferencing, and decision making for the execution and termination of nuclear forces.

The NMCS is designed to allow senior military commanders and senior government officials to monitor and assess the situation, conference with the President during crises, disseminate information, advise the President of potential response options, and capture the Presidential decision for communication to the forces.

After the Presidential decision is made, information directing the authorized action is coded into an Emergency Action Message (EAM) and is transmitted by the NMCS directly to the executing nuclear forces. The EAM is relayed to the executing forces using multiple communications networks and platforms to assure reception by the executing force. Various EAM formats are designed to expedite specific types of actions directed by the President.

Upon receipt of the EAM, military personnel at the executing forces must validate and authenticate the EAM. Validation is a check of the EAM for correct format and completeness. Authentication is a check of values entered into the EAM with values found on a sealed authenticator. If any part of the EAM fails the validation or authentication process the executing forces will not take the action directed.

All of these operations are conducted by highly trained and qualified personnel who are in a program designed to ensure personnel reliability and recognize if another individual is attempting to perform incorrect/unauthorized procedure. Sensitive operations are conducted under two person control to ensure no single person has weapon access or the ability to cause an unauthorized or inadvertent launch, or the ability to sabotage a Presidential order.

Presumably, the President as Commander in Chief of the Armed Forces, or officials specifically delegated responsibility by the President, would be the authority for the employment of strategic

non-nuclear weapon operation because of their potential employment consequences. Many of the procedures/controls, described above for nuclear forces could be adopted or adapted for the command and control of strategic non-nuclear forces. The NMCS as described above, which provides the infrastructure to support nuclear and national command and control requirements could, to the maximum extent possible, support these operations.

In that case, DoD Directive 5100.44 Master Plan for National Military Command System would be expanded to establish NMCS as the command and control means for the SECDEF and CJCS to contact the President for crisis conferencing and military executive decisions for strategic non-nuclear strike forces similar to nuclear forces. The system would be used to establish Presidential authority through authentication procedures, advise the President on strategic non-nuclear strike options and issue force direction and management messages to strategic non-nuclear forces.

Relevant elements of the NMCS could provide the President immediate access to command and control infrastructure from any location. Additionally, Combatant Commanders must ensure their communication systems provide a link between the NMCS and executing forces.

The NMCS would:

- Support conferencing and decision making between the President and senior government officials and senior military commanders.
- Direct strategic non-nuclear force employment and termination.

In conclusion, several issues related to strategic, non-nuclear force command and control need to be addressed:

- How stringent should the standards be for strategic non-nuclear command and control compared to the above standards for NCCS?
- What elements of the NMCS would be used for command and control and how would these elements be linked to the non-nuclear strategic forces? What prioritization protocols would be established to handle competing priorities?
- What systems would be used to develop a common operational picture for senior decision-makers?
- What procedures/controls should be used for Presidential authentication?
- After an execution or termination decision is made, what procedures/controls should be implemented to code the authorized action into an action message and transmit the message directly to the executing forces?
- What message authentication and validation procedures/controls should be adopted or adapted for the control of conventional strategic forces?

INTERCONTINENTAL GUN

Introduction

The intercontinental gun concept is attributed to Dr. Roderick Hyde and Dr. Lowell Wood at Lawrence Livermore National Laboratory (LLNL), who have provided briefings entitled *Global Artillery* (Dr. Roderick Hyde, November 30, 2004) and *Long Range Artillery* (Dr. Roderick Hyde, undated). The Task Force is grateful to Dr. John Foster for bringing it to our attention. As formulated the Global Artillery concept is intercontinental and able to reach any place in the world from the United States. The Long Range Artillery concept would have a maximum range of 7,000 km. If based in Guam and Diego Garcia it could reach all targets of interest in the scenarios postulated by the Task Force.

Objective

The Global Artillery concept was conceived to have the capability to promptly strike targets anywhere, anytime using conventional warheads or kinetic energy for target destruction. It would be designed for shorter preparation time than ICBMs, and flight time less than 45 minutes to any place on the globe. The objective would be to attack mobile targets and targets-of-opportunity. The projectiles would be equipped with terminal guidance to enable accurate delivery against point or small targets.

A key premise of the idea is that existing long-range weapons are not suitable. ICBMs and SLBMs have high unit costs and cost of operations. Bombers and cruise missiles are also high in cost and have long time-of-flight. Another important premise is that the high initial cost of development and construction of the gun would be amortized over a very large number of rounds fired. The gun would be designed to be a decisive force with high and sustained rates of fire comparable to 250 B-2 sorties/day equivalent to 5,000 tons/day during a campaign of equivalent in time, presumably, to experience in Afghanistan, Iran and Bosnia. The concept allows the gun to be relatively expensive, and it would be, while the warheads are kept as cheap as possible.

Description

Intercontinental range requires intercontinental velocities of about 10 km/sec, a velocity not achievable at the muzzle of conventional guns powered by chemical energy. Three types of guns were considered: the light gas gun, the electromagnetic (EM) rail gun and the EM coil gun. There is experience with all three, but of varying degree and extent.

Light gas guns are used in Ballistic Ranges for aerodynamic testing of scale models of ICBM/SLBM reentry vehicles at a high Mach Number. They were also used for atomic and molecular physics important to dissociation and ionization of air constituents in the wake of Reentry Vehicles. The rate of fire of gas guns is too low and the velocity is not sufficient for intercontinental range.

EM rail gun research has been going on to various degrees for over 20 years for various applications, including anti-armor, and catapults for aircraft carriers. Rail guns have some of the same speed and throughput concerns as gas guns. Rail guns are complex and scaling up from the laboratory devices is not straightforward.

Although coil guns have received less attention, there are some test results with hybrid chemical-coil guns indicating the potential to achieve speed and rate of fire required for global artillery. A major advantage is that energy is transferred to the projectile without contact. Another is that the concept lends itself to a modular design. The coil gun was therefore chosen for the LLNL Global Artillery concept.

Table D-3 illustrates the elements and the physical principles of a coil gun. A number of separately powered coils surround the gun tube which contains the projectile resting in a cradle or sabot. The cradle has azimuthal conductors in which a current is induced by the magnetic field and motion of the cradle. That azimuthal current flowing perpendicular to the magnetic field applied by the coil creates an axial force on the cradle that accelerates the projectile. The coils require an external power source, power storage, power conditioning, and switchgear to energize each coil at the right time.

The design parameters are:

Weight	700 kg
Payload	400 kg
Aeroshell	150 kg
Cradle	150 kg
Velocity	12 km/sec (vertical launch)
Length	1.5 km
Kinetic Energy	50 GJ
Acceleration	5,000 g
Time	0.25 sec
Power	400 GW (50% coupling)

Table D-3. Design Parameters

Technical Challenges:

- Switchgear durability and lifetime
- Coil structural life
- In-bore stability
- Atmospheric heating during flyout and reentry
- Ablation effects on aerodynamics of reentry body
- Erosion from clouds and rain
- Stability and guidance

Conclusion

The Task Force considered the characteristics of the intercontinental gun in the context of the scenarios it developed and the actions desired in order to deal with those scenarios with time

critical conventional strike. None of those actions required the very high and sustained ordnance delivery capability of the intercontinental gun.

APPENDIX E. SCENARIO DESCRIPTIONS

SCENARIO 1: NEAR PEER COMPETITOR WITH EMERGING COUNTER-SPACE CAPABILITY HAS DESTROYED U.S. LEO SATELLITE

PURPOSE OF SCENARIO

To provide a credible framework that requires a U.S. time-urgent remote response to a military attack by a well armed nation state. The fictitious adversary nation is a nation state, near-peer competitor (NPC), located at least 2000 miles from U.S. soil.

SITUATION

Adversary:

NPC is a near-peer competitor nation that has developed a nuclear capability in obvious violation of non-proliferation agreements. Concurrently it has funded the buildup of a strong conventional force. Its Air Defense is known to be an in-depth layered system with cueing radars and electronic signals measures (ESM) that would pose a difficult task for military penetration. Moreover it has a limited Counter Low Observable (CLO) warning and cueing capability for its fighter force. Recently NPC has demonstrated a long range mobile surface-to-air-missile (SAM) capability. After several years of work, NPC has tested and deployed a viable anti-satellite Automated Systems to Approach Training (ASAT) weapon. U.S. space sensors have located the ASAT base in a fixed surface facility.

NPC is currently at war with one of its neighbors. So far the war is limited in scope, but it stems from many decades of disagreements and could escalate with little prior warning. The U.S. has a long standing mutual defense pact with this neighbor, and has issued protests and warnings to NPC.

NPC has just recently employed its ground launched ASAT and disabled a U.S. satellite. The act has created a crisis in the region and in many parts of the world. NPC forces are at full mobilization, and there has been no attempt by NPC to apologize or to otherwise explain its blatant aggressive act.

Friendly:

The U.S. had not mobilized as of the time of the attack. The U.S. has regional defense pacts with several of NPC neighbors including the one in conflict with NPC. Our satellites have been observing the NPC ASAT facility on frequent orbit revisits, so the fixed location is known with great accuracy. The UN and regional bodies have been called to meetings to consider measures for restraining NPC belligerence. The U.S. is seeking international support for taking defensive military action against the aggressor. All UN members including the U.S. desire to avoid escalating the crisis and the current limited conflict into all out war.

After a hastily convened meeting, the U.S. National Security Council has recommended and the President has approved issuing an order to the Secretary of Defense to eliminate NPC ASAT capability before it can attack another U.S. satellite.

MISSION

The Secretary of Defense is hereby ordered to destroy NPC ASAT capability. This is a time urgent requirement with the goal of preventing a second attack on U.S. satellites. Limit the military means and measures to those necessary to accomplish the primary mission. Ensure a high degree of confidence in the assessment of the battle damage to the ASAT sites.

ISSUES

The Situation and the Mission generate a series of issues that the SecDef and the involved Combatant Commanders must consider. Some of the more important of these are discussed next.

Military:

Early use of force when the U.S. forces are deployed in significant numbers and yet there is no mobilization poses difficult choices for the defense leadership. Moreover, once the forces and means are selected, there will be little or no opportunity for plan rehearsals. Use of simulations and already existing plans will be relied upon in lieu of actual trials.

Civilian casualties and other collateral damage created by our attack would tend to increase the risk of escalating the current regional conflict. It is therefore important that every effort be made to mitigate this risk. NPC has strong defenses. The first strike must have a high probability of success, because if subsequent attacks become necessary, the likelihood of friendly casualties greatly increases. The corollary of this issue is the necessity of accurate and timely battle damage assessment of the first strike.

The U.S. has to expect and plan for the possibility that NPC might react quickly and violently to our attack. U.S. and allies must be prepared to defend against and to counter any such actions by NPC.

Political:

The U.S. is urging UN members to agree that unilateral U.S. action to prevent further attack on U.S. satellites is both warranted and reasonable. Diplomatic moves by the U.S. are aimed at isolating NPC from trade and other favored nation contacts. U.S. ambassadors are informing their host country leaders that the U.S. has no desire, nor does it plan to escalate the conflict, but it cannot allow such unprovoked attack on its national assets to go unanswered. The U.S. must insure that another attack cannot be made.

Domestically, the administration is fully informing the Congress about the details of the NPC aggression. In separate meetings with appropriate committees of the Congress, the Secretary of Defense is conducting briefings of the planned response to eliminate the NPC ASAT facilities. A consistent message to the Congress elicits their help for gaining public support of the American people for its rapid response to the unprovoked attack of its satellites.

Policy:

The President has issued policy guidance that only the minimum military force sufficient to achieve the mission will be used. The Secretary of Defense has issued guidance to the

Combatant Commanders that the U.S. will abide by all treaties and will not use the air space of another nation unless granted permission.

In view of the situation and the need for rapid reaction, the U.S. will not seek to gain plausible denial for its actions to destroy the ASAT capability of NPC. However, all reasonable steps will be taken to avoid collateral damage to civilians and to facilities that are not part of the ASAT complex. Nevertheless, any threat or use of force by NPC against U.S. troops will be met with sufficient power to protect its personnel and their equipment, notwithstanding the above policies.

Technical:

Is it feasible to alter some U.S. satellite orbits as a means of delaying any subsequent attacks on its satellites? If so, would that be helpful by granting the U.S. additional time for preparations for the attack?

Is there a means available to the U.S. that could be employed to disable the Command and Control and Battle Management systems of the ASAT? If so, how much added time would that give the U.S. for executing the attack?

The U.S. knows where the ASAT facilities are located. However, does it know enough about the NPC defensive capabilities that are undoubtedly in place to protect this one of a kind complex so that the U.S. has a high probability of getting access to conduct the strike needed for destroying the target? Are U.S. technical capabilities able to identify deceptive measures that might be used to misdirect the U.S. attack toward dummy facilities?

Are kinetic weapons the best (only?) available tools to do the destructive task? Given that accurate strike results are critical to determining mission success, is the U.S.'s technical capability sufficient to provide a guarantee of correct reports of results? If not, what non-technical means does the U.S. employ?

Time Parameters:

In responding to this enemy aggressive action where time urgency is critical to preventing further satellite losses, the two most important factors are how much time is needed to plan and marshal the forces, and the time needed to obtain a decision to act. The U.S. is able to gain some time by changing the orbits of the endangered satellites. This would force the adversary to change its targeting programs thereby providing the U.S. more time. In addition, before the strike the U.S. would prepare contingency plans whose assumptions might include this kind of unprovoked attack. The Defense Department could initiate briefs for the National Command Authorities (NCA) describing possible courses of action and the time elements of the decision process necessary for time urgent response. Shown on Figure E-7 is a chart that illustrates one example of an assumed time-event situation.

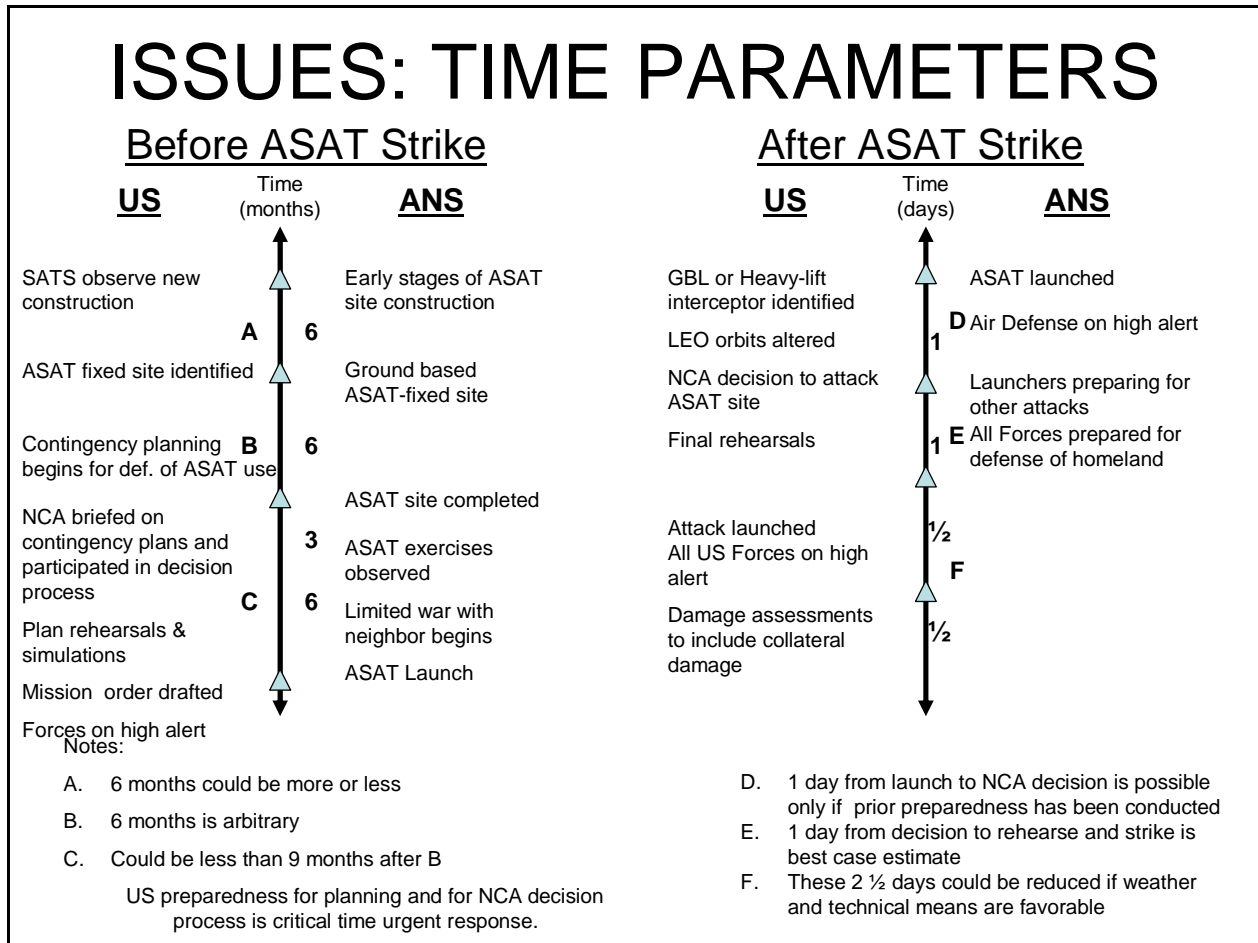


Figure E-7. Scenario 1 Time Parameter Issues

SCENARIO 2: BULK SPECIAL NUCLEAR MATERIAL BEING TRANSPORTED BY A TERRORIST GROUP

PURPOSE OF SCENARIO

To provide a credible framework that requires a U.S. time-urgent remote response to a situation within a neutral country. This fictitious neutral country is in the southern hemisphere, thousands of miles from major U.S. conventional force bases in CONUS, Europe and Asia.

SITUATION

A terrorist group has acquired hundreds of pounds of radiological material (e.g., nuclear waste) which it is transporting by rail through a neutral country. After the train arrives at a highly populated port, intelligence has learned that the material will be divided up and packaged into an arsenal of dirty bombs and then trans-shipped by sea to a wide variety of both target countries and aggressor nations. This neutral country is in the southern hemisphere, thousands of miles from major U.S. conventional force bases in Europe and Asia. By assumption, the U.S. has become aware of this threat, has tagged the appropriate rail car, and has no more than 24 hours to neutralize the threat.

MISSION

The Secretary of Defense is hereby ordered to seize or destroy this radiological material. This is a time urgent requirement with the goal of preventing the use of this material in “dirty bombs” against the U.S. or any other nation. The threat must be neutralized with high confidence and little to no collateral casualties or damage in the neutral country. Additionally, the mission should be executed without damaging the political, social or economic stability of the neutral country.

ISSUES

The Situation and the Mission generate a series of issues that the Secretary of Defense and the involved Combatant Commanders must consider. Some of the more important of these are described below.

Political:

If the country involved were an allied country the U.S. would possibly work closely with them and their military to seize and dispose of the material. However, since the country involved is a “neutral” country, whose ties cross many political boundaries, there would appear to be two major political considerations in selecting a course of action:

1. The first course of action to consider would be to work with the host nation to seize and dispose of this material. The decision for this option would depend deeply on the personal relationships and trust the U.S. may have with that country’s leadership or perhaps the military to military relationships the U.S. might have developed over the years through its foreign internal defense program. The key element here is trust in order that the mission can be

- accomplished without compromise. In choosing this course, an essential factor would be the location of this country and its proximity to other non-friendly or aggressor nations who may take either military, political or economic actions against the “host” nation who they see as aiding the United States. This option may drive the need to make any actions by the U.S. either covert or clandestine.
2. The second course of action to consider is driven by the need to ensure that operational security is maintained, to facilitate speed of action and to ensure that the terrorist group (or their surrogates that may be accompanying the material or coordinating its movement) are not alerted and remove the material to an unknown location before the U.S. can seize and neutralize it. Thus, a unilateral action by the U.S. may be more important to achieve mission success, but a plan must be in place to deal with the second and third order political consequences of such a unilateral action.

Regardless of the option, such a contingency must have planned check lists for the various congressional, diplomatic and interagency briefings and actions that would enable the U.S. to execute such an action with minimal political fallout.

U.S. ambassadors would have to be prepared to inform their host country leaders that the U.S. has no desire nor does it plan to remain as a military presence, but rather it is seizing, controlling and disposing of the material because of the damage it might cause to any nation where it might be used as a “dirty bomb.” Moreover, the U.S. should be poised to prove to the world with conclusive evidence and verified forensics of the nature of the material and the plot to use it for WMD attacks. This diplomatic effort should be prepared to execute a global information campaign, a behind the scenes diplomatic effort with other major powers including China and Russia, and an upfront and public presentation of results at the UN, and at any other international organization such as NATO or the EU, to produce compelling evidence of the justification and international importance of the time critical nature that led to the unilateral action by the United States.

Assuming that such a mission would rapidly become public knowledge, domestically, the U.S. must insure that the danger is fully understood across the various agencies and branches of the government and that the administration is fully informing the Congress about the details of the material. In separate meetings with appropriate committees of the Congress, the office of the Secretary of Defense must be prepared to conduct briefings of the planned response to seize and secure the radiological material and provide a consistent message to the Congress. One goal of these briefings would be to elicit congressional support to inform the American people, especially if the mission involves the unilateral, cross border incursion into the neutral country.

Military:

Since no major U.S. forces are based nearby, a light, rapid response force that is poised to react and is trained in the identification and handling of radiological material is needed. If the U.S. decides on a unilateral action, or even if it is done in concert with the host nation, it would be preferable to be able to carry out this mission in a clandestine manner that denies the terrorist

groups the exact knowledge of what happened to the material and also deny them, or adversary nations, the information that might be used to politically exploit this action by the United States.

Once the forces and means are selected, there will be little or no opportunity for rehearsals. In fact, because of the distance from U.S. forces' location and the time sensitive nature of the mission, force movement will have to be put into action almost immediately as other go/no go decisions and authorities are made and granted. Use of simulations will have to take place in virtual rehearsals that are embedded in the military units' mission planning systems. Moreover, existing plans for just such a contingency, and the fact that U.S. forces will have rehearsed similar missions during live exercises, will be relied upon in lieu of actual rehearsals.

Any explosive destruction of the radiological material could obviously result in civilian casualties or other collateral damage that would make the U.S.'s mission appear to be counter-productive. This could have global political ramifications and could result in increasing support for terrorists groups, especially among neutral nations. It is therefore important that every effort be made to mitigate this risk. The mission must have a high probability of success, because if the material is not seized, the terrorists may accelerate their efforts to employ such weapons. The mission must be well documented and the seized material either preserved or forensically recorded should it become necessary to justify the action in the international political arena. This is a clear requirement if the mission is executed without the permission of the sovereign neutral country.

Policy:

The President has issued policy guidance that only the minimum military force sufficient to achieve the mission will be used. The Secretary of Defense has issued guidance to the Combatant Commanders that the U.S. will abide by all treaties and will not use the air space of any nation which has not granted permission with the exception of the neutral country if it is decided that the U.S. will execute this unilaterally.

In view of the situation and the need for rapid reaction, the U.S. will not seek to gain plausible denial for its actions to seize the material. However, all reasonable steps will be taken to prevent any damage to the radiological material that may result in a hazard to the host nation civilians or nearby transportation facilities. Nevertheless, any threat or use of force by the host nation against U.S. troops will be met with sufficient power to protect U.S. personnel and their equipment, notwithstanding the above policies.

Technical:

The U.S. knows where the radiological material is located (and has tagged it) and knows of its next destination. Executing the mission while it is still on the rail car thus increases the probability of mission success. This raises several technical questions: Is it feasible to alter the radiological material in place so that it can no longer be used to create a weapon or be hazardous? If so, can that be done remotely without having to put troops on the ground and without having to actually seize the material? If it can not be neutralized remotely, can the material be treated at the site to render it harmless and thus eliminate the need to dispose of it? Unfortunately, desirable as it might be to remotely neutralize such material, feasibility is lacking.

Given the nature of the target material and the fact that an accurate kinetic strike would result at a minimum in the dispersal of radiological material (that would inevitably – correctly or not - be reported as radioactive fallout) do we have a kinetic weapon that could so completely destroy the target as to ensure that there would be no remaining hazardous radiological material? Would this weapon be effective and still meet the minimal collateral damage and loss of life criteria that has been applied to this mission? And if so, does the U.S. have the technical (remote) means to measure that all of that material has been neutralized? In the absence of a clear positive answer to these questions, the next best option would be to seize and render the material using Special Operations Forces.

Time Parameters:

In responding to a mission where time urgency is critical to preventing the division and further dispersal of the radiological material, the two most important factors are how much time is needed to obtain a decision to act and how much time is needed to plan, marshal and move the forces. The U.S. is able to gain some time by having predesignated forces on alert and have them moving toward the area of operations as soon as the situation was determined. Thus they might be prepositioned or well enroute when mission execution decisions are rendered.

The Defense Department should be prepared to initiate briefs for the NCA describing possible courses of action, time elements of the decision process necessary for time urgent response, and an execution check list to carry out the mission.

SCENARIO 3: TERRORIST TEAM WITH WMD

PURPOSE OF SCENARIO

To provide a credible framework that requires a U.S. time-urgent remote response to a situation within an unaligned or neutral country. This fictitious non-permissive regional power (e.g., heavily foliated South or Central American nation) with local security forces is over 1000 miles from the nearest major U.S. forces base.

SITUATION

A non-state actor has acquired a WMD which it plans to quickly employ against the U.S. or its allies. The WMD is being carried in a large backpack. This backpack is temporarily being held in a village in a non-permissive Central or South American country. This area is being watched by sophisticated, but imperfect intelligence sources. The team with the backpack could depart at any time. The adversary is understandably skittish, and will flee at the slightest indication from local sources, the media, or intelligence indications provided by the host nation. By assumption, the U.S. has become aware of this weapon, knows the approximate location, and has no more than 24-48 hours to attack or capture the weapon before it is moved and perhaps lost.

MISSION

The Secretary of Defense is hereby ordered to capture or destroy the WMD. This is a time urgent requirement with the goal of removing it from the terrorist network. It is desired to execute the mission:

1. With high confidence that the backpack is captured or destroyed. The U.S. must have positive confirmation that it is destroyed.
2. With consideration to prevent or minimize any political, social or economic damage to the stability of the non-aligned host nation.
3. In such a manner to cause minimal casualties to innocent bystanders.
4. With the understanding that collateral damage in the host nation is a lesser consideration than millions killed in the U.S. with successful use of the WMD by terrorists.
5. With the understanding that U.S. citizens and the rest of the world must be shown positive evidence of the existence of the weapon and terrorist intent after the capture to assure positive acceptance of U.S. action.
6. The number one goal of the U.S. is to capture and disarm the weapon.

ISSUES

The Situation and the Mission generate a series of issues that the Secretary of Defense and the involved Combatant Commanders must consider. Some of the more important of these are: any sensible solution to this scenario must include location and observation of the target along with target destruction or capture. The analysis should assume a wide range of dwell times for the backpack – from a few hours to a few days.

Political:

If the country involved were an allied country the U.S. would possibly work directly with their military and law enforcement agencies to capture, if possible, the WMD. However, since the country involved is non-aligned, its ties cross many political, social and economic boundaries; there would appear little flexibility in selecting a course of action. Cooperating with the country's officials would be ideal but that is not feasible in this case.

The course of action to consider is driven by a decision that any discussion with the host nation will compromise the operational security of the mission. As a result the WMD would be moved prematurely. To ensure the terrorist group is not alerted and dispersed before the U.S. can execute the plan, and to ensure and facilitate speed of U.S. military action, a unilateral action by the U.S. may be the only option to achieve mission success. This would then require that the U.S. have a full plan in place to deal with the second and third order political consequences of such a unilateral action.

Such a contingency must have planned checklists for the various diplomatic, domestic, and interagency briefings and actions that would enable the U.S. to execute such an action with minimal political fallout.

Diplomatically U.S. ambassadors would have to be prepared to inform their host country leaders what the U.S. has done and that the U.S. has no desire nor plan to remain as a military presence (if the U.S. entered the country with ground forces to capture or destroy this WMD; in fact the U.S. would already be out of the country if the mission was successful), but rather that the U.S. is executing this mission to capture these international criminals and their device. Moreover, the U.S. should be poised to prove to the world with conclusive evidence and verified forensics of the identity of these individuals and the evidence of their connection to international terrorist acts and organizations. This diplomatic effort should include a global information campaign, a behind-the-scenes diplomatic effort with other major powers in the region, and a public presentation of forensically valid evidence at the UN. Moreover, the U.S. should be prepared to immediately address and receive the support of other key international organization such as NATO or the EU in condemning terrorism and supporting this mission. All efforts should produce compelling evidence of the justification and international importance of the mission and should clearly lay out a time line that explains the time critical nature that drove the decision to make this a unilateral action by the United States.

Domestically the U.S. should assume that such a mission would rapidly become public knowledge. Accordingly the U.S. must insure that the value of eliminating these weapons and terrorist leaders who have them is fully understood across the various agencies and branches of the government and that the administration fully informs the Congress about the details of the mission. In separate meetings with appropriate committees of the Congress, the office of the Secretary of Defense must be prepared to conduct briefings of the planned mission to capture or destroy this WMD. One goal of these briefings would be to elicit congressional support to inform the American people, especially if the mission involves unilateral, cross border incursion into the non-aligned country.

Military:

Since no major U.S. forces are based nearby, a light, rapid response force that is poised to react and is trained to identify and capture WMD must be on standby. It would be preferable to carry out this mission in a clandestine manner that denies the exact knowledge of what happened to the WMD until well after the time that exploitation of information and knowledge has occurred.

Once the forces and means are selected, there will be little or no opportunity for rehearsals. In fact, because of the distance from U.S. forces' location and the time sensitive nature of the mission, force movement will have to be put into action almost immediately as other go/no go decisions and authorities are made and granted. Use of simulations will have to take place in virtual rehearsals that are embedded in the military units' mission planning systems. Moreover, existing plans for just such a contingency, and the fact that U.S. forces will have rehearsed similar missions during live exercises, will be relied upon in lieu of actual rehearsals.

If time and distance prevents the use of ground forces, then a kinetic strike from either in theater or CONUS becomes the option. Again, this may occur with or without the knowledge of the host nation. Any kinetic destruction of the WMD could obviously result in civilian casualties or other collateral damage, particularly since the specific nature of the WMD is unknown. This could have global political ramifications and could result in increasing support for terrorist groups, especially among neutral nations. It is therefore important that every effort be made to mitigate this risk. The circumstances of the mission that drove it to a time critical kinetic strike must be well documented. Every effort must be employed to identify the weapon and the terrorists immediately after the strike. This may involve the almost immediate arrival of a U.S. or international law enforcement forensic team following the kinetic strike.

Policy:

The President has issued policy guidance that only the minimum military force sufficient to achieve the mission will be used. The Secretary of Defense has issued guidance to the Combatant Commanders that the U.S. will abide by all treaties. In the case of sending in ground troops, the policy will be to limit the route in to those countries that have given permission with the exception of any country that it is necessary to fly over, including the targeted neutral country, if it is decided that the U.S. will execute this unilaterally.

In view of the situation and the need for rapid reaction, the U.S. will not seek to gain plausible denial for our actions. However, all reasonable steps will be taken to prevent any damage to the host nation civilians or nearby facilities although the U.S. will accept collateral damage versus lose the weapon. Nevertheless, any threat or use of force by the host nation against U.S. troops will be met with sufficient power to protect U.S. personnel and their equipment, notwithstanding the above policies.

Technical:

The U.S. knows about where the backpack is but not precisely. This situation raises several technical questions: Is it feasible to isolate the area where the target is long enough to find it in a building by building search. Does the U.S. have any useful sensors?

Are U.S. technical capabilities able to provide deceptive measures that would cover the fact that the U.S. has captured the WMD or to cover the U.S. attack?

Does the U.S. have a weapon that is capable of being accurate enough to travel over 1000 miles, strike a precise target, penetrate the target and destroy the WMD without dispersing it? If so, does the U.S. have the remote sensors that will enable confirmation that the weapon was destroyed?

Time Parameters:

In responding to a mission where time urgency is critical to strike a specific place at a specific time in order to capture or destroy the WMD, the two most important factors are:

- how much time is needed to obtain a decision to act; and
- how much time is needed to plan, marshal and move the forces or to bring weapons and sensors to bear.

In the Troops on the Ground option, the U.S. is able to gain some time by having pre-designated, trained forces on alert and have them moving toward the area of operations as soon as the situation was determined. Thus they might be prepositioned or well enroute when mission execution decisions are rendered. Similarly, in the kinetic strike scenario, time is gained by having the weapons and sensors in a ready to launch status either in aircraft, on the ground, on ships or submarines, or in space.

The Defense Department should be prepared to initiate briefs for the NCA describing possible courses of action, time elements of the decision process necessary for time urgent response, and an execution check list to carry out the mission.

SCENARIO 4: ATTACK ON A TERRORIST MEETING

PURPOSE OF SCNEARIO

To provide a credible framework that requires a U.S. time-urgent remote response to a situation within an unaligned or neutral country. This fictitious non-aligned country is in Central Asia, in the northern hemisphere and is over 1000 miles from the nearest major U.S. forces base.

SITUATION

The United States has learned that a group of senior terrorist leaders and operatives who are considered high value targets (HVTs) will meet within the next 24 hours in a known location within a populated area of a city. The city is located in a non-aligned nation in Central Asia with whom the United States has diplomatic relations and has conducted some foreign internal defense and mobile training team deployments, but has no formal treaty or mutual defense arrangements. By assumption, the U.S. has become aware of this meeting, knows the approximate location, and has no more than 24 hours to attack or capture these HVTs.

MISSION

The Secretary of Defense is herby ordered to capture or kill these HVTs. This is a time urgent requirement with the goal of removing these HVTs from the terrorist networks and exploiting any intelligence material or knowledge that these HVTs may have about the terrorist network. The mission should be executed with high confidence and in such a manner to minimize casualties to innocent bystanders. The execution of the mission should also be planned and executed so as to restrict damage to the building and if possible to the specific meeting place. Additionally, the mission should be executed with consideration to prevent or minimize any political, social or economic damage to the stability of the non-aligned host nation.

ISSUES

The Situation and the Mission generate a series of issues that the Secretary of Defense and the involved Combatant Commanders must consider. Some of the more important of these discussed below.

Political:

If the country involved were an allied country, the U.S. would possibly work directly with their military and law enforcement agencies to capture, if possible, the HVTs. However, since the country involved is non-aligned, its ties cross many political, social and economic boundaries; there would appear to be two major political considerations in selecting a course of action:

1. Since the U.S. has diplomatic relations with the host nation and have conducted some military to military training with them, the first course of action to consider would be to work with the host nation and “assist” them in the capture or killing of these international terrorist leaders. The decision for this option would depend on the personal relationships and trust with that country’s leadership or perhaps the military to military relationships the U.S.

might have developed over the years through its foreign internal defense training program. The key element here is balancing trust against the need for mission accomplishment. Can the U.S. accomplish the mission without a premature compromise that would cause cancellation of the meeting?

Note: In choosing this course, a key consideration is the location of this country and its proximity to aggressor nations who may take either military, political or economic actions against the “host” nation for “aiding” the United States. To avoid such second order effects of this mission, this option may drive any actions by the U.S. with the host nation to be either covert or clandestine in nature.

2. The second course of action to consider is driven by a decision that any discussion with the host nation will compromise the operational security of the mission thus resulting in the meeting being cancelled. To ensure that the terrorist group is not alerted and either disperse or cancel the meeting before the U.S. can execute the plan, unilateral action by the U.S. may be more important to achieve mission success. This would then require that the U.S. have a full plan in place to deal with the second and third order political consequences of such a unilateral action.

Regardless of the option, such a contingency must have planned checklists for the various diplomatic, domestic, and interagency briefings and actions that would enable the U.S. to execute such an action with minimal political fallout.

Diplomatically U.S. ambassadors would have to be prepared to inform their host country leaders what the U.S. has done and that it has no desire nor plan to remain as a military presence (if the U.S. entered the country with ground forces to capture or kill these HVTs; in fact it would already be out of the country if the mission was successful), but rather that the U.S. is executing this mission to capture these international criminals. Moreover, the U.S. should be poised to prove to the world with conclusive evidence and verified forensics of the identity of these individuals and the evidence of their connection to international terrorist acts and organizations. This diplomatic effort should include a global information campaign, a behind-the-scenes diplomatic effort with other major powers in the region, and a public presentation of forensically valid evidence at the UN. Moreover, the U.S. should be prepared to immediately address and receive the support of other key international organizations such as NATO, the EU or the Arab League in condemning terrorism and supporting this mission. All U.S. efforts should produce compelling evidence of the justification and international importance of the mission and should clearly lay out a time line that explains the time critical nature that drove the decision to make this a unilateral action by the United States.

Domestically the U.S. should assume that such a mission would rapidly become public knowledge. Accordingly the U.S. must insure that the value of eliminating these terrorist leaders and operatives is fully understood across the various agencies and branches of the government and that the administration fully informs the Congress about the details of the mission. In separate meetings with appropriate committees of the Congress, the office of the Secretary of Defense must be prepared to conduct briefings of the planned mission to capture or kill these HVTs. One goal of these briefings would be to elicit congressional support to inform the

American people, especially if the mission involves the unilateral, cross border incursion into the non-aligned country.

Military:

Since no major U.S. forces are based nearby, a light, rapid response force that is poised to react and is trained to identify and capture HVTs must be on standby. If the U.S. decides on a unilateral action, or even if it is done in concert with the host nation, it would be preferable to be able to carry out this mission in a clandestine manner that denies the terrorist groups the exact knowledge of what happened to their leaders until well after the time that exploitation of these terrorists' information and knowledge has occurred.

Once the forces and means are selected, there will be little or no opportunity for rehearsals. In fact, because of the distance from U.S. forces' location and the time sensitive nature of the mission, force movement will have to be put into action almost immediately as other go/no go decisions and authorities are made and granted. Use of simulations will have to take place in virtual rehearsals that are embedded in the military units' mission planning systems. Moreover, existing plans for just such a contingency, and the fact that our forces will have rehearsed similar missions during live exercises, will be relied upon in lieu of actual rehearsals.

If time and distance prevents the use of ground forces, then a kinetic strike from either in theater or CONUS becomes the option. Again, this may occur with or without the knowledge of the host nation. Any kinetic destruction of the HVTs and their meeting place could obviously result in civilian casualties or other collateral damage. This could have global political ramifications and could result in increasing support for terrorist groups, especially among neutral nations. It is therefore important that every effort be made to mitigate this risk. The circumstances of the mission that drove it to a time critical kinetic strike must be well documented. Every effort must be employed to identify the terrorists as they arrive at the site and, if possible to gain DNA identification of the killed terrorists immediately after the strike. This may involve the almost immediate arrival of a U.S. or international law enforcement forensic team following the kinetic strike.

Policy:

The President has issued policy guidance that only the minimum military force sufficient to achieve the mission will be used. The Secretary of Defense has issued guidance to the Combatant Commanders that the U.S. will abide by all treaties. In the case of sending in ground troops, U.S. policy will be to limit the route in to those countries that have given permission with the exception of any country that it is necessary to fly over, including the targeted neutral country, if it is decided that the U.S. will execute this unilaterally.

In view of the situation and the need for rapid reaction, the U.S. will not seek to gain plausible denial for its actions. However, all reasonable steps will be taken to prevent any damage to the host nation civilians or nearby facilities although the U.S. will expect damage to the meeting place. Nevertheless, any threat or use of force by the host nation against U.S. troops will be met with sufficient power to protect U.S. personnel and their equipment, notwithstanding the above policies.

Technical:

The U.S. knows where and when the meeting is to take place and has a good idea who will be in attendance. This situation raises several technical questions: Is it feasible to positively identify individuals as they arrive at the meeting place assuming they all have to pass through at least one of the known entrances to the building? Is it feasible to positively identify who is in an interior, secured room at any given time? If so, can either of those identification events be done remotely without having to put troops on the ground and without having to actually touch the individuals? If it can not be done through remote sensors, can specially equipped troops on the site execute this key portion of the mission from a remote yet nearby distance?

Are U.S. technical capabilities able to provide deceptive measures that would cover the fact that the U.S. has captured the HVTs or to cover the U.S. attack? This would also offer the possibility of interrogating the prisoners and possibly carrying out immediate follow on strikes.

Does the U.S. have a weapon that is capable of being accurate enough to travel over 1000 miles, strike a precise target, penetrate the target and kill the occupants in an interior meeting room, yet not kill or destroy the surrounding building infrastructure? If so, does the U.S. then have the remote sensors that enable confirmation as to which attendees are at the meeting? Does the U.S. also have sensors that would be delivered either separately or with the weapon that could confirm identity of the casualties after the strike?

Time Parameters:

In responding to a mission where time urgency is critical to strike a specific place at a specific time in order to kill or capture specific HVTs, the two most important factors are:

- how much time is needed to obtain a decision to act; and
- how much time is needed to plan, marshal and move the forces or to bring weapons and sensors to bear.

In the Troops on the Ground option, the U.S. is able to gain some time by having predesignated, trained forces on alert and have them moving toward the area of operations as soon as the situation was determined. Thus they might be prepositioned or well enroute when mission execution decisions are rendered. Similarly, in the kinetic strike scenario, time is gained by having the weapons and sensors in a ready to launch status either in aircraft, on the ground, on ships or submarines, or in space.

The Defense Department should be prepared to initiate briefs for the NCA which would describe possible courses of action, time elements of the decision process necessary for time urgent response, and an execution check list to carry out the mission.

SCENARIO 5: PREEMPTING NUCLEAR MISSILE ATTACK

Scenario 5 posits a regional power (not a near-peer) who is threatening to strike either the U.S. or one of its regional allies with a small arsenal of nuclear-armed ICBMs unless the U.S. or its allies accede to their demands. This adversary has roughly ten mobile ICBMs moving among what appears to be a much larger number of Hardened and Deeply Buried Under Ground Facilities (HDB UGFs) and large civilian structures. An additional three HDB UGFs are used for storage of spare nuclear weapons and missile support facilities. The adversary head-of-state has yet to order the missiles launched. If adversary sensors detect a U.S. attack, it is assumed the head-of-state will be informed in as little as one minute. Communication with dispersed missiles will take one to five minutes, and ICBM launch will occur approximately ten minutes after receipt of the launch order. Therefore, the U.S. must either achieve complete surprise or succeed within ten minutes of the adversary discovering the attack.

The mission is to terminate the blackmail threat by whatever means necessary. The U.S. is assumed to possess missile defenses which might absorb a very few missiles which survive the attack, but it is preferred not to depend on these defenses. If the threatened attack were poised against one of the U.S.'s allies, it is doubtful that a missile defense would be operable within the region. The mission must be accomplished with high confidence, and while avoidance of massive civilian casualties is desirable, this is secondary to ending the threat to the lives of millions of people.

This scenario suggests the use of CSLBM and/or CACM attacks to offset and adversary's choice of remaining in HDB UGFs, or disbursing mobile ICBMs for survivability. CSLBMs have the advantage of rapid response but lack the capability to successfully attack HDB UGF targets. CALCM's have the capability against HDB UGF, but take longer in the delivery phase.

ATTRIBUTE	DESCRIPTION	CONCERNS/SENSITIVITIES
Adversary	Regional power	Political: Actions could lead to all out war. Potential to adversely affect the regional balance of power. Administration faces consequences for perceived overreaction or lack of responsiveness. Political direction is high confidence attack. Within reason the U.S. has time to plan the right response as the adversary is expected to play their current threat hand for a while, because once they launch, all potential leverage is lost.
Location	Regional power missile capability within a small region not near a major population center	Political: Adversary's leadership may be playing brinkmanship with no intent to fire. U.S. response will depend on a number of factors: Assessment of adversary's intent, assessment of U.S. attack mission success, effectiveness of U.S. missile defense. Technical: Ability to attack while adversary's missiles are in HDB UGFs.

		Hardness of shelters may not be known. Effectiveness of adversaries warning and C2 systems. Collateral damage is assumed to not be a major player because of the threat to the U.S., the relative remoteness of the targets and the presumed use of conventional strike weapons.
ISR	High probability satellite ISR is available.	<p>Political: Can non-space borne ISR be employed in a potentially non-permissive environment?</p> <p>Technical: Does sufficient intel exist to support target assessment and political decision making? Is satellite ISR adequate or sufficient?</p>
Target Type	Assumed to be of sufficient hardness to require large numbers of conventional warheads or nuclear attack.	Technical: Multiple possible target locations require hitting all fixed locations where missiles may be located. Hardened target analysis required to determine if multiple hits required.
Target Access	Facility locations are known, but launcher locations within a facility are unknown, even before dispersal.	<p>Political: Assessment of the adversary's leadership CONOPS for missile movement, survival, launch readiness, etc.</p> <p>Technical: Ability to strike without giving sufficient warning for dispersal.</p>
Target Evasiveness	Area narrowing required to limit possible dispersed locations.	Technical: Area narrowing requires time to develop.
US Forces	Conventional SLBM or stealthy cruise missiles required are only available in U.S. forces.	<p>Political: Balance need for surprise with need to notify friendly nations of intent.</p> <p>Technical: Selection of global strike force highly dependent upon specific location and target hardness</p>
Mission	Destroy all missiles, weapons and support equipment without the adversary being able to respond with an attack on the U.S.	<p>Political: Political decision will heavily depend on military assessment of mission success.</p> <p>Technical: Highly dependent upon target posture, fixed or deployed. .</p>

Attribution/Deniability	Mission is so large, unique and in response to a threat that deniability is not necessary.	Political: Political guidance does not include deniability. Technical: Exceedingly difficult to prevent attribution.
Time to prepare	Once conflict intensity rises, adversary bluff is perceived to be called, presumably 24 hours to 48 hours.	Technical: Extremely challenging to compress targeting preparations and attack assessments into this timeframe to facilitate a high confidence decision to execute. Limited time to pre-position forces.
Targeting preparations	Targeting procedures need to have been preplanned at least to precise location of HDB UGF.	Technical: Probably apply more weapons to offset target hardness uncertainty.
Retargeting capability	Desired after initial attack to ensure all nuclear forces destroyed.	Political: Assuming successful attack, some efforts to gain control of nuclear weapons and material desired. Special Ops forces may be required.
Blue Force Risk	Adversaries Defenses Missile launch before strike. SOF ground forces capture.	Political: Adversary bluffing about capability. Escalation to all out war. Technical: Unmanned strike forces eliminate risk to blue strike forces. Manned forces involve greater risk but are capable of adapting to adversary actions.
Collateral Damage	Limit US attack to missile shelters and C2 to minimize collateral damage to maximum extent possible.	Political: Political fall-out will probably be directly related to collateral damage depending on the target nation. Technical: Limitations of both CSLBMs and CACM to meet speed and effectiveness necessary for success without collateral damage.
Decision-making	Presidential decision required.	Political: Difficulty in predicting adversary's actions and his decision to transition from bluffing to action. Technical: Providing sufficient high fidelity intelligence and strike planning to provide a high confidence in mission success.

Command and Control	Required to permit last minute choice of attack methods.	Technical: Clear lines of command are required because of the integrated support required for either military operation chosen.
Attack Surprise	Surprise is deemed essential to mission success.	<p>Political: Risk of attack surprise being compromised if forewarning provided to allies and the target nation.</p> <p>Technical: Unlikely that surprise might be compromised, provided ISR does not provide a tipoff.</p>
Time to Strike	CSLBM presumably within a few hours (e.g. 2 hours). CACM requires alert aircraft, launch to a positive control point that may be accomplished during decision time and then time of flight of CACM.	<p>Political: Pre-positioning of forces reduces response time but also could provide warning to the adversary. This could have two effects: Adversary's recognition that the U S will not be blackmailed and alternatively, it increases the adversary's warning.</p> <p>Technical: Assuming preposition of strike forces, CSLBM can attack with about 30 minutes. CACM may take up to two hours from launch.</p>
Damage Assessment	HDB UGF damage can be ascertained by satellite imaging but no way of determining damage within. High confidence damage assessment needs to be accomplished in less than two hours.	<p>Political: Adversary's defenses may limit the use of ISR over flight. SOF forces for control of nuclear weapons and materials risks capture and hostage negotiation.</p> <p>Technical: Damage assessments will probably be limited to structural damage assessment without absolute confirmation by SOF forces .</p>

Overall Assessment

The preempting nuclear missile attack scenario is the most challenging of the five scenarios. A decision maker could use both CSLBM and CACM strike weapons and coordinate their attacks to optimize the strengths of each. Targeting the Command and Control systems increases the probability of preventing the dispersal of mobile missiles. Depending on the adversary's radar coverage, CACM, because of its stealth, offers both penetrability without detection and hard target disruption capability. The need for almost total destruction of both deeply buried and mobile targets without warning is why this is considered the most difficult scenario.

APPENDIX F. PROGRAMS OF RECORD

STANDOFF OPTIONS FOR PROMPT GLOBAL STRIKE—Current Development programs or operational systems of record

1. Joint Air-To-Surface Standoff Missile (JASSM): JASSM is a survivable, precision cruise missile capable of launch from outside of area defenses to kill hard, medium-hardened, and soft targets. It is a 2,000-lb class weapon with a 1,000-lb multi-purpose (blast/frag/ penetrator) warhead. It can cruise autonomously in adverse weather, day or night, to defeat fixed or relocatable targets with enhanced GPS accuracy. JASSM is integrated on the B-1, B-2, B-52 & F-16 and will be integrated on the F-15E & F-35. JASSM Baseline range is ~200 NM. Total production for USAF is expected to be 2,400 missiles; the total for the US Navy is TBD. Total program value is approximately \$3 Billion. The JASSM Extended Range (JASSM-ER) and JASSM Maritime Interdiction (JASSM-MI) programs are two JASSM follow-on programs in their initial stages. The JASSM-ER (Extended Range) would increase standoff distance to over 500 NM and the JASSM-MI would add anti-ship capability.

2. Joint Standoff Weapon (JSOW): JSOW is a family of three 1,000-lb class (penetrating warhead with 240 lb HE), air-to-surface glide weapons that provide a survivable, standoff outside point defenses capability against a range of targets during day/night/all weather conditions. It has a demonstrated standoff range of 63 NM and a potential range of 120 NM when powered. It is both land and carrier based. Production of JSOW “A” & “B” variants have been deferred to meet demand for the JSOW “C” variant. AGM-154 JSOW “C” - Unitary variant is in FRP. It has a 2 stage British Broach lethality package for use against point targets. By Oct. 2002 more than 1,000 JSOWs had been manufactured. Plans call for DoD to spend more than \$4 B to buy 14,000 JSOWs through 2007. JSOW will be employed on F/A-18A/B,C/D,E/F; AV-8B; F-16C/D; F-15E; F-117; B-1B; B-52.

3. Small Diameter Bomb (SDB): SDB is a 250lb class (50 lb HE) standoff air-to-ground weapon that increases weapon load out on fighter & bomber aircraft by a factor of 4. SDB Increment I is intended for fixed and stationary targets using anti-jam SAASM INS/GPS (aided by a wide area differential GPS solution) and stand off capability. SDB Increment II will provide the warfighter standoff capability against moving targets in adverse weather. SDB has a standoff range of more than 60 NM with a CEP of 3 m for a surveyed target. Initial integration of the SDB is with the F-15E. Follow-on integration may occur with the F/A-22, F-35, UCAV, F-16 (Block 30/40/50), F-117, A-10, MQ-9, B-1, B-2, B-52. B-2 could carry between 64 and 192-216 SDBs. USAF plans to acquire 12,000 fixed-target SDBs and about 12,000 moving-target SDBs. SDB is a joint USAF/USN program. SDB is also a potential payload for standoff carrier vehicles. i.e., Conventional ICBM, SLBM, IRBM, etc.

4. TOMAHAWK Land Attack Missile (TLAM): TLAM is a 4,000 lb class weapon with a 1,000 lb warhead. There are 4 TLAM configurations currently in inventory – TLAM-N (SSN variant), TLAM Block IIIC (conventional unitary warhead), TLAM Block IIID (submunition dispenser) & TLAM Block IV (conventional unitary warhead). In Aug. 2004 the Navy awarded a contract (FY04–FY08) for procurement of up to 2,200 TLAM Block IVs (Tactical Tomahawks or TACTOMs). The Tomahawk Block IV has a range of 900 NM. Block IV upgrades allow the

strike controller to flex the missile in flight to alternate targets or loiter over the battlefield awaiting an assignment to a time critical target. The TACTOM Torpedo Tube Launch (TT TTL) program was initiated to ensure Tomahawk Block IV capability on all non-Capsule Launch System (CLS) US attack subs. USN will receive 100 TTLs. Development program costs are \$58.5M (est.).

5. Stand-off Land Attack Missile (SLAM): AGM-84E Harpoon/SLAM Block 1E is a 1500 lb class (488 lb HE) intermediate range (~60 NM) air-to-surface weapon system designed to provide day, night and adverse weather precision strike capability against high value land targets and ships in port. AGM-84E uses an inertial navigation system with GPS, infrared terminal guidance, and is fitted with a Tomahawk warhead for better penetration. SLAM can be launched from land-based or aircraft carrier-based F/A-18 Hornet aircraft. The SLAM-ER (Expanded Response) Block 1F, a major upgrade to the SLAM has a greater range (150+ NM), a titanium warhead for increased penetration, and software improvements which allow the pilot to retarget the impact point during the terminal phase of attack (~ 5NM). The SLAM-ER development contract was awarded to McDonnell Douglas Aerospace (now BOEING) in Feb. 1995. SLAM-ER achieved its first flight in March of 1997. All 700 Navy SLAM missiles were planned to be retrofitted to SLAM-ER configuration with about 500 between FY 1997 and FY 2001. The SLAM-ATA (Automatic Target Acquisition) Block 1G, a follow on enhancement to SLAM-ER with re-attack capability and a new seeker, is under development. SLAM-ER-ATA will improve SLAM-ER's capability to strike counter measure protected targets in cluttered spaces, such as urban areas, in poor weather.

6. Conventional Trident Modification (CTM): DoD proposed precision Trident D-5 and extended range ATACMS in 2003 to diversify its strategic options, as part of a broader, long-term strategy to develop new Prompt Global Strike (PGS) capabilities. The \$1/2 billion program initially proposed in the 2007 President's Budget (and still before Congress) would have converted existing Trident II D-5 missiles (2-4 D-5s per Ohio class sub) into 7,000 NM conventional strike weapons, by fitting them with modified Mark 4 re-entry vehicles equipped with GPS for navigation update and a reentry guidance and control (trajectory correction) segment to perform 10 m class impact accuracy. A kinetic energy projectile warhead is used because the re-entry vehicle's mass (~300 lbs) and hypersonic impact speed provide sufficient kinetic energy to produce the required "tailored effects" for many targets of interest. CTM offers the promise of accurate conventional strikes with 30 minute or less flight times, depending on the range to target, with little or no warning to the targeted adversary and ample pre-launch warning times for other nations who might be in a position to detect the CTM's launch and/or trajectory. PGS/CTM is the subject of a congressionally mandated 2007 NAS study.

7. Conventional Strategic Missile (CSM): CSM is based on the use of now de-activated Peacekeeper ICBMs to be sited and launched from Vandenberg AFB in California, and would deliver an inert payload to a target up to 7,000 NM away in less than 30 minutes. Given the exquisite target guidance system already embodied in the Peacekeeper and the reentry vehicle GPS/INS guidance provided by CTM development, target CEPs of less than 10 meters can be anticipated. Like the CTM, the kinetic energy of the incoming kinetic energy projectile warhead (> 2000 lbs) will be sufficient to provide the required "tailored effects" on many potential targets of interest. Currently, USAF uses Peacekeeper components in its Minotaur III & IV space launch vehicles: Minotaur III is a 3-stage suborbital rocket, also used as a target vehicle for

testing U.S. missile defense systems and similar missions; Minotaur IV is a heavier-lift 4-stage space launch vehicle, used to place satellites (up to 3800 lbs.) into low-altitude orbit. Orbital was recently awarded its first Minotaur IV contract by the USAF to launch the Space-Based Surveillance System (SBSS) satellite.

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APPENDIX G. ACRONYMS AND ABBREVIATIONS

ABL	Airborne Laser
AC	Air conditioning
ACM	Advanced Cruise Missile
ACTD	Advanced Concept Technology Demonstration
AF	Air Force
AFB	Air Force Base
AFRL	Air Force Research Laboratory
AFSAB	Air Force Scientific Advisory Board
AGM	Air-to-ground missile
ALCM	Air-Launched Cruise Missile
AMaRV	Advanced Maneuvering RV
ARRMD	Advanced Rapid Response Missile Demonstrator
ASAT	Automated Systems to Approach Training
ASD	Assistant Secretary of Defense
ASD(NII)	Assistant Secretary of Defense (Networks and Information Integration)
ASUW	Antisurface Warfare
ATD	Advanced Technology Demonstration
BDA	Battle Damage Assessment
C2	Command and Control
C3	Command, Control, and Communication
C4I	Command, Control, Communications, Computers, & Intelligence
CALCM	Conventional Air-Launched Cruise Missile
CBM	Conventional Ballistic Missile
CEP	Circular Error Probable
CJCS	Chairman of the Joint Chiefs of Staff
CLO	Counter Low Observable
CNA	Computer Network Attack
CND	Computer Network Defense
CNO	Computer Network Operations
COA	Courses of Action
COCOMs	Combatant Commands
COMSEC	Communications Security
CONUS	Continental United States
CSF	Critical Success Factors
CSM	Conventional Strategic Missile
CTM	Conventional Trident Modification
DARPA	Defense Advanced Research Projects Agency
DDG	Guided Missile Destroyer
DE	Directed Energy
DEW	Directed Energy Weapon
DI	Deeply Integrated
DNA	Deoxyribonucleic Acid
DNI	Director of National Intelligence

DoD	Department of Defense
DOE	Department of Energy
DSB	Defense Science Board
DSMAC	Digital Scene-Matching Area Correlation
DSP	Defense Support Program
DTRA	Defense Threat Reduction Agency
EA	Electronic Attack
EAM	Emergency Action Message
E ²	Enhanced Effectiveness
ELINT	Electronic Intelligence
EM	Electromagnetic
EMD	Electromagnetic Defense
EMP	Electromagnetic Pulse
EP	Electronic Protection
ES	Electronic Warfare Support
ESM	Electronic Signals Measures
EU	European Union
EW	Electronic Warfare
FALCON	Force Application and Launch from the Continental United States
FEL	Free Electron Laser
FID	Foreign Internal Defense
GIG	Global Information Grid
GN&C	Guidance, Navigation, and Control
GPS	Global Positioning System
HDB UGF	Hardened and Deeply Buried Under Ground Facilities
HDBT	Hard and Deeply Buried Target
HPM	High Power Microwave
HUMINT	Human Intelligence
HVT	High Value Target
HyTech	Hypersonic Technology
I&W	Indications and Warnings
ICBM	Intercontinental Ballistic Missile Systems
IC	Intelligence Community
ID	Identification
IMU	Inertial Measurement Unit
INF	Intermediate-Range Nuclear Forces
INS	Inertial Navigation System
INS/GPS	Inertial Navigation System with Global Positioning System
IO	Information Operations
IR	Intelligence Requirement
ISR	Intelligence, Surveillance and Reconnaissance
IT	Information Technology
JASSM	Joint Air to Surface Standoff Missile
JASSM-ER	Joint Air to Surface Standoff Missile
JASSM-XR	Joint Air to Surface Standoff Missile
JSOTF	Joint Special Operations Task Force

JSSCM	Joint Supersonic Cruise Missile
JSOW	Joint Standoff Weapon
L/D	Lift-to-Drag
LCMS	Low Cost Missile System
LEO	Low Earth Orbit
LETB	Life Extension Test Bed
LLNL	Lawrence Livermore National Laboratory
LOCAAS	Low Cost Autonomous Attack System
MASINT	Measurement and Signatures Intelligence
MIA	Military Intelligence Agency
MILDEC	Military Deception
MITL	Man-In-The-Loop
MTT	Multi-Target Tracking
MW	Microwave
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NCA	National Command Authorities
NCCS	Nuclear Command Control System
NGA	National Geospatial-Intelligence Agency
NMCS	National Military Command System
NPC	Near-Peer Competitor
NPR	Nuclear Posture Review
NSC/WHMO	National Security Council/White House Military Office
NSPD	National Security Presidential Directive
OCONUS	Outside the Continental United States
ODNI	Office of the Director of National Intelligence
ONR	Office of Naval Research
OPNAV	Operational Navy
OPSEC	Operations Security
OSD	Office of the Secretary of Defense
PBV	Post-Boost Vehicle
POTUS	President of the United States
PSYOP	Psychological Operations
PTAN	Precision Terrain Aided Navigation
R&D	Research and Development
RADAR	Radio Detecting and Ranging
RATTLRS	Revolutionary Approach to Time-Critical Long Range Strike
RB	Radar Beacon
RF	Radio frequency
RGM	Radar Guided Missile
ROE	Rules of Engagement
ROM	Rough Order of Magnitude
RV/RB	Reentry Vehicle/Reentry Body
SAM	Surface-to-Air-Missile
SBSS	Space-Based Surveillance System
SDB	Small Diameter Bomb

SDI	Strategic Defense Initiative
SEAL	Sea, Air, Land (Special Forces team member)
SECDEF	Secretary of Defense
SIGINT	Signals Intelligence
SLAM	Standoff Land Attack Missile
SLAM-ER	Standoff Land Attack Missile-Expanded Response
SLBM	Submarine/Sea-Launched Ballistic Missile
SLCM	Sea-Launched Cruise Missile
SMACM	Surveilling Miniature Attack Cruise Missile
SNM	Special Nuclear Materials
SOC	Special Operations Command
SOC Korea	Special Operations Command Korea
SOCCENT	Special Operations Command Central
SOCEUR	Special Operations Command, Europe
SOCJFCOM	Special Operations Command, Joint Forces Command
SOCOM	Special Operations Command
SOC PAC	Special Operations Command, U.S. Pacific Command
SOC SOUTH	Special Operations Command, U.S. Southern Command
SOF	Special Operations Forces
SONAR	Sound Navigation and Ranging
SSBN	Ship, Submersible, Ballistic, Nuclear
SSGN	Submersible, Ship, Guided, Nuclear
START	Strategic Arms Reduction Treaty
STRATCOM	Strategic Command
SWERVE	Sandia Winged Energetic RV Experiment
TBM	Theatre Ballistic Missile
TEL	Transporter-Erector-Launcher
TERCOM	Terrain Comparison
TF	Task Force
TLA	Target Location Accuracy
TLAM	Tomahawk Land Attack Missile
TLE	Target Location Error
TOR	Terms of Reference
TPED	Tasking, Processing, Exploitation and Dissemination
TPPU	Task, Post, Process and Use
TPS	Thermal Protection System
TRL	Technology Readiness Level
TSSAM	Tri-Service Standoff Attack Missile
TTL	Tagging, Tracking and Locating
U.S.	United States
UAV	Unmanned Aerial Vehicles
UGM	Underwater Guided Missile
UN	United Nations
USAF	United States Air Force
USCENTCOM	United States Central Command
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology and Logistics

USD(I)	Under Secretary of Defense for Intelligence
USD(P)	Under Secretary of Defense for Policy
USMC	United States Marine Corps
USN	United States Navy
USSOCOM	United States Southern Command
USSR	Union of Soviet Socialist Republics
USSTRATCOM	United States Strategic Command
WMD	Weapons of Mass Destruction
WWI	World War I
WWII	World War II